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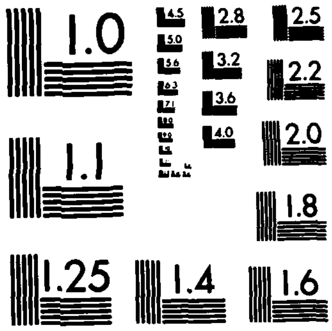

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NAVAL POSTGRADUATE SCHOOL

Monterey, California

THESIS

ANALYSIS OF ACOUSTIC AMBIENT NOISE IN
MONTEREY BAY, CALIFORNIA

by

Christopher Jacob Elles

December 1982

Thesis Advisor: O.B. Wilson, Jr.

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surf condition was investigated over a frequency range of 10-2500 Hz. Discussions of methods used during data-taking and analysis, the computer program itself, and typical data for certain surf conditions are reported. Some tentative conclusions are drawn from the results and presented. Comparison of one-third octave band levels indicate that the highest low-frequency levels exist for "heavy" surf conditions, especially for the band at 500 Hz, with levels decreasing in strength with increasing range from shore. These results are consistent with conclusions reached by the earlier investigators that significant contributions to ambient noise are made by sources in the surf zone.

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Analysis of Acoustic Ambient Noise in Monterey Bay, California

by

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN ENGINEERING ACOUSTICS

from the

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ABSTRACT

Magnetic tape recordings, made in 1980 and 1981 by previous investigators using sonobuoys, of acoustic ambient noise in the south-eastern parts of Monterey Bay for various stations under various surf conditions, were analyzed. A computer program was developed and used with sonobuoy calibration data to correct "raw-data" to absolute sound pressure levels. The variation of omnidirectional levels with range from the beach as a function of surf condition was investigated over a frequency range of 10-2500 Hz. Discussions of methods used during data-taking and analysis, the computer program itself, and typical data for certain surf conditions are reported. Some tentative conclusions are drawn from the results and presented. Comparison of one-third octave band levels indicate that the highest low-frequency levels exist for "heavy" surf conditions, especially for the band at 500 Hz, with levels decreasing in strength with increasing range from shore. These results are consistent with conclusions reached by the earlier investigators that significant contributions to ambient noise are made by sources in the surf zone.

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I. INTRODUCTION

Ambient acoustic noise in the ocean arises from many sources, such as wind, waves, ship traffic, biological organisms, thermal and hydrodynamic effects, rain, and seismic phenomena. Wenz [Ref. 1] has reported results of investigations to determine the most probable origin of observed noise. Referring to wind-related noise sources specifically, Wenz states that "... shallow-water levels ... are in general about 5 dB higher than the corresponding deep-water levels ... at the same frequency and wind speed." Urick [Ref. 2] reports that the shallow-water ambient noise at a given frequency "... is a mixture of three different types of noise: (1) shipping and industrial noise, (2) wind noise, and (3) biological noise," where at "... a particular time and place, the mix of these sources will determine the noise level ...," which is variable with respect to time and location. However, Arase and Arase [Ref. 3] report that "... in shallow water, the noise between 20 and 400 Hz may also be wind dependent ...," where the cross-correlation of the noise levels to wind speeds (based on a scale from one, perfect correlation, to zero, no correlation) is "... substantial and about equal .. at 500 Hz ..." for shallow and deep water. They state that "... despite many measurements of wind-dependent noise, the mechanism by which the noise is

generated remains unexplained since there are so many concurrent effects which could be contributing."

One source in the category of "wind-related" noise in shallow water that must be considered is the breaking of waves on a beach. Very few studies have been conducted to report measurements of ambient noise levels due to the contributions made by the surf. Penhallow and Dietz [Ref. 4] conducted experiments to correlate waveheight with wind speed at a frequency of 630 Hz, reporting that "... wind speed is a more significant variable than wave height under transient conditions in determining the SPSL..." (sound pressure spectrum level.) However, "... waveheight is as good an indication of SPSL at 630 cps as wind speed for relatively steady winds." Expanding this type of investigation to a broader frequency range, Wilson, Wolf, and Ingenito [Ref. 5-7] conducted research in Monterey Bay, California in 1980 and 1981 to "... make at least a preliminary measurement to determine whether surf-generated noises ought to be included in ambient noise models." Gagliardi [Ref. 8], working with Wilson, et al., in 1981, attempted to find a preferred horizontal directionality to the ambient noise. The observations made during their combined research [Ref. 7] were that an "... anisotropy in the horizontal directionality of the low-frequency ambient noise in the shallow waters of Monterey Bay ..." does exist, where the results lead to a conclusion that "... the breaking

of waves does contribute significantly to the shallow water ambient noise."

This work used the raw data that was recorded on magnetic tape during the Wilson, et. al. [Refs. 5-7] and Gagliardi [Ref. 8] experiments to further investigate surf contributions to the shallow-water ambient noise in Monterey Bay. The experiments were conducted in May of 1980 and March to September of 1981, and used "on line" spectrum analysis techniques for the data to formulate conclusions. The omnidirectional hydrophone outputs from the acoustic sensors used for data taking were not corrected for system response, so spectrum plots were not reduced to absolute levels. This was the first major objective of this thesis - to develop and use a computer program that would correct "raw spectrum data" to absolute levels. Kinsler, Frey, Coppens and Sanders [Ref. 9] gives a general formula to calculate a "smoothed" spectrum level ($\langle SPL \rangle_{\Delta f}$), for a given bandwidth ("Δf") as

$$\langle SPL \rangle_{\Delta f} = SPL - 10 \log \Delta f \qquad (1)$$

where "SPL" is the sound pressure level (dB re 1 micro Pa).

Once these absolute spectrum levels were obtained, the variation of the omnidirectional levels with range from the beach as a function of surf condition could be investigated. This would be done by comparing certain band levels of spectra made at the same time, but at different ranges, using the formula given by Kinsler, et al. [Ref. 9] as:

$$IL = 10 \log \left(\sum_i 10^{IL_i/10}\right), \tag{2}$$

where "IL_i" are the individual band levels for the "I" bands, and "IL" is the overall band level.

The following pages describe the methods used during data taking by Wilson, et al. [Refs. 5-7] and Gagliardi [Ref. 8] and follow-on data analysis, discussion of the computer program used to obtain absolute spectrum levels, some typical data for certain surf conditions, and analysis of the data as a function of range during different surf conditions. This thesis presents information that would contribute to and support further research and study of ambient noise due to surf in shallow water regions. Comments on the values obtained from these results and tentative conclusions/ indications are drawn from the results and presented.

II. EXPERIMENTAL APPARATUS AND PROCEDURE

A. ACOUSTIC SENSORS

The raw data were taken during the experiments in Monterey Bay using U.S. Navy directional lofar (DIFAR) sonobuoys, model AN/SSQ-53A. This type of buoy has a radio frequency transmitter for relaying the signals from a hydrophone package which consists of an omnidirectional hydrophone; two crossed, horizontally-disposed pressure-gradient or particle-velocity sensors; a magnetic compass; a data transmission system where receiving equipment can separately resolve the omnidirectional sound pressure and the North-South and East-West components of the sound wave; and the capability to have an operator steer one of the cosine receiving patterns from the horizontal gradient sensors, relative to the earth's horizontal magnetic field direction, by adjusting the phase shift in one of the sub-carriers of the signal.

The operating frequency range for these sonobuoys is from about 10 Hz to 2500 Hz, with a low frequency roll-off of about -6 dB per octave in sensitivity below about one kHz designed into the system.

The hydrophone packages were set to deploy at depths of 28.0 m where water depths would allow. To ensure that the package would not hit bottom, some buoys were modified

to reduce hydrophone depth. Data taken in August and September of 1981 were done with modified buoy cables where the hydrophone was at a depth of 30.5 or 61.0 m. The normal buoy life is four hours, and to prevent buoy drift during this time, they were tethered to an anchored float. To determine whether spurious noise was introduced using this method, comparison tests of the spectra from anchored and nearby free-floating buoys were made which showed that the tethering did not cause spurious noise.

B. EXPERIMENTAL PROCEDURE DURING DATA COLLECTION

The eastern part of Monterey Bay was used for data taking because of its accessibility and varying surf conditions. The shoreline of the southeastern part of the bay is relatively straight for a distance of about 20 Km, approximately on a magnetic north-south heading. Data taking was done off the beach at Fort Ord, California, where the bathymetry is relatively uniform perpendicular to shore out to a range of 15 Km, where the depth is about 200 m. The depth increases rapidly further seaward in the Monterey submarine canyon, reaching 1500 m at a range of about 19 Km. The beaches at Fort Ord are characterized by Bascom [Ref. 10] as steep, with a predominant swell from the northwest, and with prevailing winds coming from the west to northwestern direction. Swell wave energy is somewhat focused due to the geometry of the bay, resulting in wave heights approaching the beach being approximately

ten percent greater than those measured at the entrance to the bay.

The anchoring systems and the sonobuoys were set in place by the R/V ACANIA, a 126-foot vessel operated by the Naval Postgraduate School to conduct oceanographic instruction and research. Station locations are indicated in Figure 2.1 and listed in Table I.

Water temperature data obtained from mechanical bathythermographs taken in the vicinity of different sonobuoy stations indicate a mixed layer depth of about 10 m in spring and about 20 m during summer months. Typical sound speed profiles are shown in Figure 2.2 through 2.5, which indicate location of the sample and type of surf conditions. Data were taken with hydrophones below the mixed layer depth for the most part, except at stations nearest the shore.

Wind speeds were obtained from anemometers on the R/V ACANIA and on a bluff above the Fort Ord beach during the May 1980 experiment, while records from the U.S. Weather Service were used for the 1981 experiments. Surf conditions were determined by the data takers based on subjective opinions coupled with the knowledge of the wind speeds. The captain of the R/V ACANIA also provided his estimate of sea states during placement of the sonobuoys.

Signals from activated sonobuoys were received and processed by equipment located on a bluff above the beach at Fort Ord during the May 1980 experiments, and by equipment

located on the roof of Spanagel Hall at the Naval Postgraduate School campus during the 1981 experiments. Tape recordings of the signals from individual buoys were made utilizing a Honeywell 5600E tape recorder/reproducer onto a 14 channel, one-inch magnetic tape. Certain channels had direct recording of signals (which at times were attenuated when noise levels were high), FM recording of signals, or recording of the horizontal directionality of one sonobuoy utilizing a demultiplexer system and creating a cardioid receiving pattern, which could be rotated by the operator through phase-shift adjustments. A time code was recorded on one channel, as well as a voice track dedicated to comments by the data takers as the experiments progressed. On-line spectrum analysis was made of signals utilizing a Hewlett-Packard 3582A spectrum analyzer, controlled by a Hewlett-Packard 9825A Calculator, with plots made on a Hewlett-Packard 9862A Calculator Printer. During the 1980 experiment, a bottom-mounted platform located beyond the surf zone was equipped with an omnidirectional hydrophone, a vertically oriented geophone, and a type J-11 moving-coil acoustic projector, and, at certain times, recordings of signals from these instruments were made since they were connected electrically by cables to the shore station. During the experiments, comparisons of plots made on-line with those from tape playback were made to ensure close agreement existed. A total of 35 reels of tapes of recorded

data were made - 11 from the 1980 experiments and 24 from the 1981 experiments - each containing approximately one hour and fifteen minutes of data on any given channel.

The major effort in the data analysis conducted so far in Ref. [7] has been to examine the horizontal directionality of the ambient acoustic noise in Monterey Bay, by noting the differences in noise levels for various orientations of the cardioid receiving pattern in the on-line data plots. Some effort was devoted to analysis of the omnidirectional hydrophone signals. However, all spectral analyses made before those made by this author were not corrected for system response. Calibrations of several sonobuoys were made for omnihydrophone channels only to determine the overall system sensitivity from the acoustic pressure sensor to the receiver output. The results of these calibrations were recorded on tape cartridges of the 9825A calculator or put into a logbook for historical purposes, and were used in the work reported here.

C. EXPERIMENTAL PROCEDURE DURING DATA ANALYSIS

The system used to analyze the data recordings is shown in Figure 2.6. The HP3582A spectrum analyzer, which performs a 256-point sampling and Fast-Fourier Transform (FFT) of signals, was used in the "RMS" average mode, where a new spectrum is combined with a partial result on point-by-point basis using a root-mean-square (RMS) calculation. The averaging results in a smoothing of the noise variations,

but does not reduce the level of the noise. The number of averages normally used was 128, which requires 75 seconds of signal sampling for the 500 Hz scale case, and 68 seconds for the 1.0 kHz and 2.5 kHz scale cases (which were the three bandwidth cases normally used.) Due to the point sampling characteristic of the analyzer, actual ranges for the scales are 0-520 Hz, 0-1040 Hz, or 0-2560 Hz for the 500 Hz, 1.0 kHz, and 2.5 kHz scales respectively. The HANNING passband window was used since it provides a better amplitude/frequency resolution for general noise measurements. The single-channel analysis parameters/specifications for the above bandwidth cases and the HANNING window are listed in Table II.

An estimate of what timeframes would be useful for future analysis was made by listening to all data recordings, both over the loud speaker and from the voice track. The time code translator permitted the noting of times during which improper sonobuoy operation or contaminating noises, such as boat noise, would preclude any meaningful interpretation of ambient noise. The ancillary test equipment was used to make note of relative signal strengths by visual means and for testing any electronic equipment.

Only the FM record channels (omnidirectional hydrophone outputs) were to be analyzed, since a demultiplexer and directional listening unit were not available to analyze the composite signals with directional information on the direct record channels. Absolute spectrum levels (SL) can

be determined from eq. (1), modified for computer use (discussed later) to:

$$SL = NL-HS + atten - gain, \quad (3)$$

where "NL" is the noise level from the spectrum analyzer (dBV), "HS" is hydrophone sensitivity (dB re 1V/micro Pa), "atten" is attenuation required during recording (dBV), "gain" is that amount of signal lost during recording as determined by calibration signals added to "10 log Δf" (whose value for any given channel or scale is listed in Table III), combined to give the absolute spectrum level (dB re 1 micro Pa).

Calibration data from 15 different sonobuoy calibration runs made in 1980 and 1981 on "typical" sonobuoys were used to obtain average sensitivity levels. Using the "curve fitting" standard pac program for the Hewlett-Packard HP-67 calculator, a mathematical formula was obtained as a "best fit" approximation to average values for frequency bands of 0-200 Hz, 201-1000 Hz, 1001-1900 Hz and 1901-2560 Hz. These bands were selected because the plot of average levels resembled either a linear or logarithmic curve in these bands, and "best fit" numerical values were in excellent agreement with average values. The calibration curve that was used is seen in Figure 2.7. The curve is a smoothing of data points taken every 100 Hz, where values below 50 Hz were obtained through extrapolation. These values were used in the computer program because performance specifications

were not available, nor were sonobuoys calibrated before use during the data taking experiments. The limits of the laboratory calibration response are considered to be of the same order of magnitude as those for the AN/SSQ-57 sonobuoy [Ref. 11], which vary from $\pm$ 3.5 dB at 10 Hz, to $\pm$ 1.5 dB at 440 Hz, to $\pm$ 3.5 dB at 2500 Hz.

The computer program also contains a section that calculates an overall band level (OBL) for a given frequency range based on the selected spectrum scale. These ranges were 50-2500 Hz for the 2.5 kHz scale; 20-1000 Hz for the 1.0 kHz scale; and 10-500 Hz for the 500 Hz scale. Also calculated are 1/3-octave band levels for various center frequencies based on the spectrum scale selected. For the 500 Hz scale, center frequencies are 125 Hz and 250 Hz; for the 1.0 kHz scale, an additional 500 Hz center frequency level is calculated; for the 2.5 Hz, additional 1000 Hz and 2000 Hz center frequency levels are calculated. All of these values for band levels are displayed on the absolute spectrum plots utilizing a modified form of eq. (2):

$$\mathrm{OBL} = 10 \log \left(\sum_i 10^{SL_i + 10 \log \Delta f} \right), \tag{4}$$

where

$$IL_i = SL_i + 10 \log \Delta f, \tag{5}$$

with "SL_i" being the "ith" spectrum level, and "Δf" the bandwidth as determined by the spectrum scale selected (listed in Table III.)

D. COMPUTER PROGRAM DISCUSSION

Since the HP 3582A spectrum analyzer performs a 256-point sampling and FFT of signals, a unique computer program must be used to account for these 256 samples (whose values are stored in separate "bins" in the computer memory) to determine absolute spectrum levels. The basic flow diagram of the program is seen in Figure 2.8, and the entire program is given as Appendix A.

Since the HP 9825A computer uses its own unique "HPL" language, Appendix B discusses the essential areas of the basic program and the subroutines.

When running the program, the user is required to enter several values or key information that will be used in computation (such as dB values for attenuation and gain) and/or will be displayed on the plot (such as spectrum start time, plot comments, station information, and tidal information.) The most crucial entry that must be made is the scale that was used on the HP 3582A analyzer, because different values and sections of the program are used by the calculator to obtain absolute spectrum levels. The scales that can be used by this program are: 500 Hz, 1.0 kHz, or 2.5 kHz.

III. ANALYSIS OF DATA AND DISCUSSION OF RESULTS

Although over 100 hours of raw data were recorded for the omnidirectional sonobuoy output signals, many hours of the recordings were not useful for data analysis. Reasons for this were: (1) some recordings were from free-floating sonobuoys whose position could not accurately be determined; (2) some of the recordings were made with geophones, or devices used in sound propagation tests involving an acoustic projector or underwater explosions, and were not really useful for this study; (3) in some cases, only one sonobuoy was operational so that no comparison of ambient noise levels could be made at different ranges from shore; (4) some recordings were contaminated by noise from boats, as, for example, during sonobuoy deployment when ship noise from the R/V ACANIA saturated the low frequency part of the spectrum; (5) recorded signals indicated that the sonobuoy was not operating correctly.

Ambient noise data were categorized into three levels of surf activity based on subjective opinions recorded by the investigators during the 1980 and 1981 experiments. These levels are referred to as "heavy", "moderate", or "low" surf conditions. To support this categorization the information available from the California Coastal Data Collection Program monthly summary reports [Ref. 12-14] for the Santa

Cruz, California "WAVERIDER" accelerometer buoy was used. This buoy, used to measure deep water wave energy located at 36°53.4 North, 122°04.3' West at a water depth of 70 meters, was considered to be the most indicative of what surf conditions would be like within Monterey Bay. Table IV is a summary of significant wave heights and wave energy as measured by this buoy at certain times and days in 1980 and 1981. The subjective categories of surf conditions associated with these values are also listed in Table IV. (The other time periods given are for plots that will be used for data analysis later in this chapter.) A relative wave energy strength, based on the low surf conditions and associated wave energy of April 17, 1981 are listed to provide correlation between deep water wave energy strengths with observed surf conditions.

Comparison of ambient noise levels as a function of range from shore were made by using average 1/3-octave band levels for center frequencies of 125, 250, 500, 1000, and 2000 Hz. These values were obtained from spectra taken at approximately ten minute intervals for a 70-90 minute period, during which surf conditions can be considered to be reasonably constant. Utilizing the recorded clock time, sampling for spectral analysis was started at the same instant for either two or three sonobuoys that were operational at different stations. Typical plots for each type of surf condition for the 0-2560 Hz bandwith, with several 0-1060 Hz bandwidth plots included for comparison, are shown in Figure 3.1 through Figure 3.15.

There appear to be reasons to suspect that operation of the sonobuoys at station 2 and station 3 during the May 1980 experiments (Figures 3.1, 3.2 and 3.3) was not normal because of the sharp drop off (about 10 dB) of spectrum levels at approximately 600 Hz (station 2) and 800 Hz (station 3). The spectrum levels are also up to 10 dB greater at various frequencies compared to plots taken at low surf conditions in 1981 (Figures 3.5 and 3.7). By comparison, wave energies differ only by about 30% as can be seen in Table IV. Although only two sonobuoys were active during the 1981 data plots, further analysis will utilize values for low surf conditions taken during both of these timeframes as two separate entities.

Inspection of these plots reveal several trends: (1) the more intense the surf condition, the greater the contribution to lower frequency levels (under 800 Hz); (2) for a given surf condition, the spectrum levels tend to be lower at lower frequencies (under 800 Hz) at greater ranges from shore; (3) at higher frequencies (over 1000 Hz), spectrum levels become more nearly constant as a function of range for any given surf condition, and at greater ranges from shore, these levels may even increase, believed to be due to wind and wave noise from the open sea; (4) the greater the surf condition, the higher the overall spectrum level of the plot; (5) low surf condition plots contain low-frequency line components (under 500 Hz), believed to be radiated from an underwater discharge of a coolant pump at an electrical power

plant at Moss Landing, California, about 15 Km north of the beach at Fort Ord; (6) high frequency lines (over 2000 Hz) seen at all surf conditions, are due to biological sources, believed to be from dolphins.

Average band-level values for these three surf conditions are summarized in Table V. The values for the center frequencies of 125 Hz, 250 Hz, and 500 Hz were from 0-1030 Hz plots; those for 1000 Hz, 2000 Hz, and overall band levels (OBL) were from 0-2560 Hz plots. Figure 3.16 through Figure 3.19 are graphs of these values for a given surf condition. Several tendencies are indicated by these results: (1) under all surf conditions, the lower frequency 1/3-octave band levels (125 Hz, 250 Hz, and 500 Hz) are greater than the higher 1/3-octave band levels (1000 Hz and 2000 Hz); (2) lower frequency levels tend to decrease at greater ranges from shore, whereas higher frequency levels tend to increase at greater ranges from shore; (3) for these surf conditions, the 500 Hz 1/3-octave band level tends to be higher than the 250 Hz 1/3-octave band level indicating that the contribution from the surf is larger at 500 Hz than at 250 Hz; (4) as surf conditions become greater, the 250 Hz and 500 Hz 1/3-octave band levels tend to become greater than that at 125 Hz, indicating a masking effect of lower frequency sounds (such as that of the electric power plant and either near or distant shipping); (5) for these surf conditions, the 2000 Hz 1/3-octave band level tends to be greater than the 1000 Hz

level, with both tending to increase with range from shore, indicating a greater contribution from open sea noise.

For comparison, Figure 3.20 through Figure 3.24 are graphs of the average values in Table V of the same 1/3-octave band level for various surf conditions. Other tendencies, besides those commented on above, can be seen: (1) further indications that the 1980 low surf conditions values are unrealistic due to improper sonobuoy operation are supported by noting that in Figure 3.21, 3.22 and 3.23, levels are higher than the moderate surf condition values; (2) in all cases, heavy surf conditions have the highest 1/3-octave band levels, indicating the contribution surf makes to ambient noise; (3) except for the suspected 1980 low surf condition values, moderate surf levels are greater than low surf levels, again indicating the contributions from the surf to noise levels; (4) the greatest difference in values between heavy surf and low surf conditions is the 500 Hz 1/3-octave band level, indicating that surf contributions are most significant near frequencies of 500 Hz; (5) higher frequency 1/3-octave band levels (1000 Hz and 2000 Hz) differ less in value for all surf conditions, and tend to increase slightly with range, indicating a lesser contribution to ambient noise from the surf and a greater contribution from open sea noise.

Figure 3.25 is a graph of the overall band levels for the 2.5 kHz scale plots as listed in Table V. Comparing the

relative deep water wave energy strengths of Table IV to this graph (noting that the 1980 low surf condition levels are higher than those for moderate surf conditions for two of three stations), it is seen that the noise levels at moderate ranges increase quite rapidly with increases in surf severity and with values for deep water wave energies. For example, at a range of 3 Km, there is about an 18 dB noise level increase from low to heavy surf conditions (1981 values), which corresponds to an intensity ratio of about 63, whereas relative wave energy strengths vary only by a factor of five from low to heavy surf conditions. Since for these data, increasing surf intensity was also associated with higher winds, this indicates that deep water wave energy values are not the only indicator of noise generation. Very likely other factors must be considered in predicting noise arising from surf, such as beach bathymetry and phase of the tide, in addition to deep water wave energies or wave height at the surf zone.

These tendencies give support to the conclusions of Wilson, et. al. [Ref. 7] that the breaking of waves can contribute significantly to the shallow water ambient noise. Further analysis of the sonobuoy cardioid output, as well as additional data of ambient noise levels as a function of range from the beach for a given surf condition, may make possible an estimation of the acoustic source level of the breaking surf for various surf conditions and associated

transmission loss beyond the surf zone. Further analysis of the propagation of the sound from the surf zone could then be made with the goal of providing a prediction model for ambient noise levels due to this phenomenon.

TABLE I

SONOBUOY STATION DATA

1980 Stations

Station Number	Latitude North	Longitude West	Range from beach (km)	Water Depth (ft)
1	Not available	Not available	0.51	43
2	" "	" "	1.02	82
3	" "	" "	1.96	112
4	" "	" "	4.05	196

1981 Stations prior to 16 Apr 81

Station Number	Latitude North	Longitude West	Range from beach (km)	Water Depth (ft)
D	36°40.70'	121°52.00'	4.35	210
E	36°40.38'	121°50.95'	2.74	156
F	36°41.70'	121°54.48'	8.44	294

1981 Stations on and after 16 Apr 81

Station Number	Latitude North	Longitude West	Range from beach (km)	Water Depth (ft)
D	36°41.00'	121°51.06'	3.19	195
E	36°40.72'	121°50.04'	1.44	116

TABLE II

HP-3582A SPECTRUM ANALYZER-SINGLE CHANNEL ANALYSIS AND HANNING PASSBAND WINDOW-PARAMETERS/SPECIFICATIONS

FREQ SPAN	TIME RECORD LENGTH	CALCULATED POINT SPACING	HANNING EQUIV NOISE BW
500 Hz	500 msec	2 Hz	3.00 Hz
1 kHz	250 msec	4 Hz	6.00 Hz
2.5 kHz	100 msec	10 hz	15.0 Hz

For HANNING passband only:

3 dB Bandwidth: (0.58 ± 0.05) % of span

Shape factor: [(60 dB b.w.)/(3 dB b.w.)]: 9.1 ± .2

Overall Accuracy: -1.5 dB ± 0.5 dB

TABLE III

COMPUTER PROGRAM ATTENUATION AND GAIN VALUES
BY TAPE RECORDER CHANNEL AND ANALYZER SCALE

1980 Values

Taperecorder Channel	Attentuation (dB)	Analyzer scale gains (dB) 2.5 kHz	1.0 kHz	500 Hz
1	28.5	11.5	7.5	4.5
2	28.0	11.5	7.5	4.5
3	28.6	11.3	7.3	4.3
4	28.2	11.6	7.6	4.6

1981 Values

Taperecorder Channel	Attentuation (dB)	Analyzer scale gains (dB) 2.5 kHz	1.0 kHz	500 Hz
1	28.5	11.2	7.2	4.2
2	28.0	11.3	7.3	4.3
3	28.6	11.1	7.1	4.1
4	28.2	11.3	7.3	4.3

TABLE IV

DEEP WATER WAVE, SURF, AND
WIND SPEED MEASUREMENTS AND COMPARISON

Date/Time (Local)[1]	Significant Wave Height (cm)[1]	Wave Energy (cm^2)[1]	Surf Condition Category[2]	Estimated Wind Speed (kts)[3]	Data Analysis Times (Local)[4]	Relative Wave Strength[5]
21 May 80/1508	134.8	1136.5	Low	4-6	1245-1514	1.5
22 May 80/2108	230.8	3328.3	Moderate	20-25	2112-2230	4
27 Mar 81/2115	254.5	4048.9	Heavy	30-35	1841-1952	5
17 Apr 81/0206	114.0	812.1	Low	8-10	1945-2200 (16 Apr 80)	1

NOTES:

1 - Deep water wave measurements from the Santa Cruz "WAVERIDER" accelerometer buoy [Ref. 12-14] at times nearest to data analysis times.

2 - Category based on subjective opinions of data takers.

3 - Speed based on anomometers on R/V Acania and bluff at Fort Ord beach (1980) or U.S. Weather Service Bureau data (1981).

4 - Data analysis times are for data discussed throughout Chapter 3.

5 - Relative strengths based on scale where 1 is wave energy of the 17 Apr 81 value.

TABLE V

AVERAGE ONE-THIRD OCTAVE BAND LEVELS (IN dB re 1 micro Pa) AND OVERALL BAND LEVELS (OBL) - FOR THE 2.5 kHz ANALYZER SCALE

HEAVY SURF CONDITION (1841-1952 on 27 Mar 1981)

1/3-OCTAVE CENTER FREQUENCY (Hz)	STA E (2.74 Km)	STA D (4.35 Km)	STA F (8.44 Km)
125	106.6	101.6	98.5
250	110.5	104.7	100.7
500	113.5	106.9	101.9
1000	96.4	94.1	94.3
2000	99.0	98.3	97.7
OBL	122.5	116.7	112.7

MODERATE SURF CONDITION (2112-2230 on 22 MAY 1980)

1/3-OCTAVE CENTER FREQUENCY (Hz)	STA 2 (1.02 Km)	STA 3 (1.96 Km)	STA 4 (4.05 Km)
125	97.8	97.1	96.0
250	95.1	94.7	93.3
500	95.7	95.5	94.0
1000	91.4	92.1	91.6
2000	93.1	93.8	93.9
OBL	108.6	108.6	108.0

LOW SURF CONDITION

	1245-1514 on 21 May 1980			1945-2700 on 17 Apr 1981	
1/3-OCTAVE CENTER FREQUENCY (Hz)	STA 2 (1.02 Km)	STA 3 (1.96 Km)	STA 4 (4.05 Km)	STA E (1.44 Km)	STA F (3.19 Km)
125	93.6	94.8	95.3	88.2	89.4
250	96.3	97.9	97.9	85.9	87.7
500	95.2	98.8	97.3	86.9	89.3
1000	87.7	94.2	92.0	82.2	84.5
2000	90.6	91.9	92.5	85.8	87.6
OBL	107.4	110.8	109.8	101.6	103.2

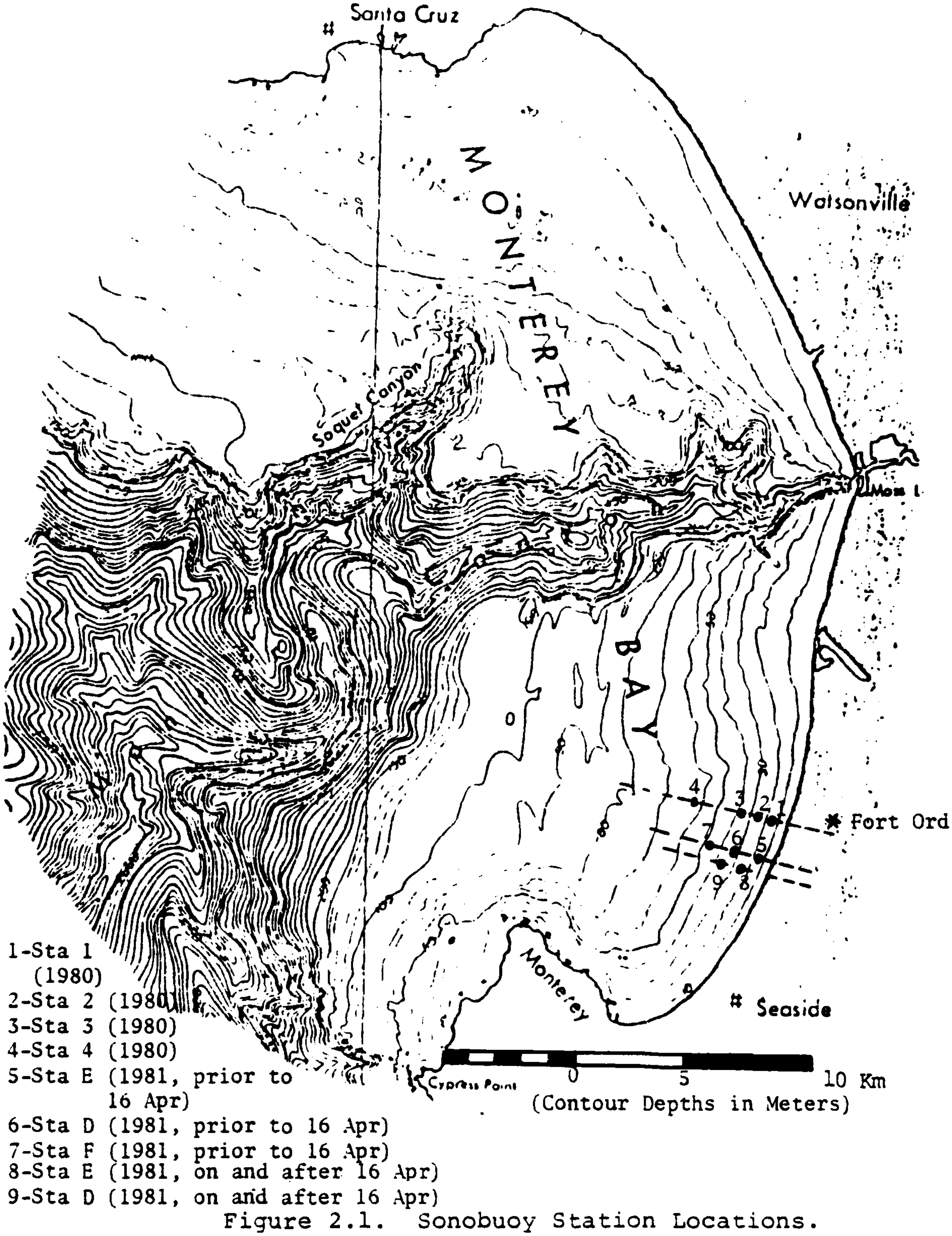

Figure 2.1. Sonobuoy Station Locations.

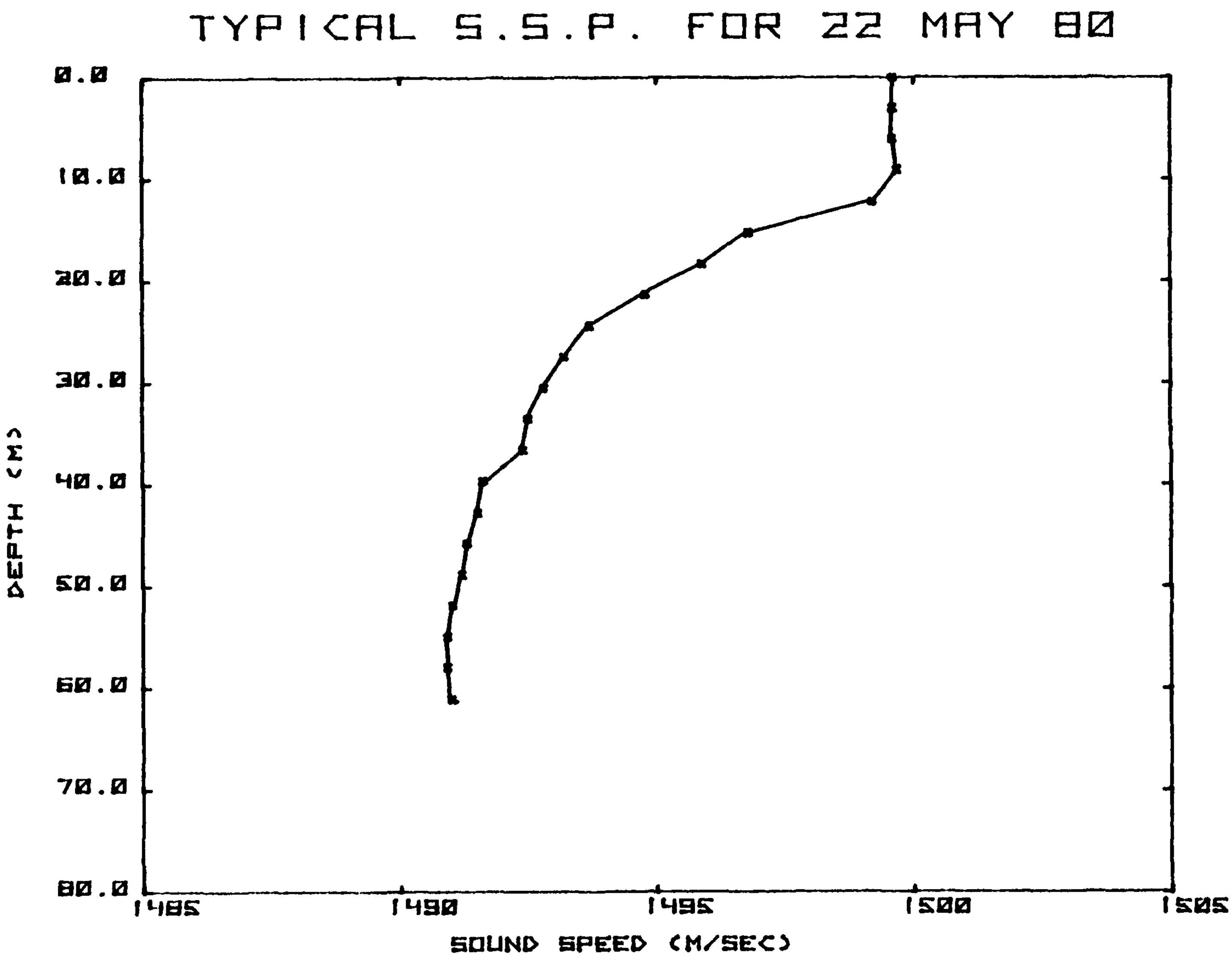

Figure 2.2. Typical Sound Speed Profile for 22 May 80 Near Station 4.

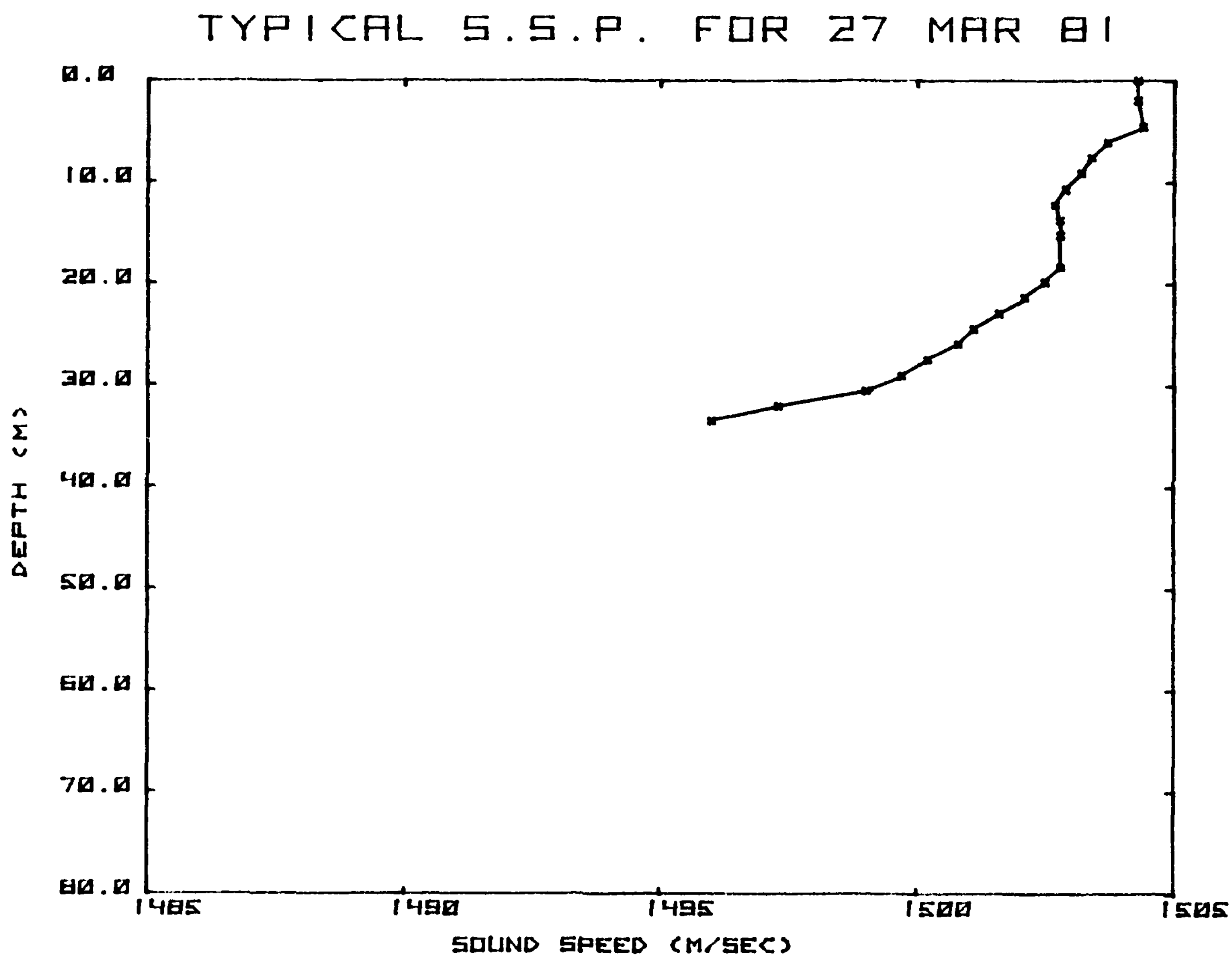

Figure 2.3. Typical Sound Speed Profile for 27 Mar 81 Near Station E.

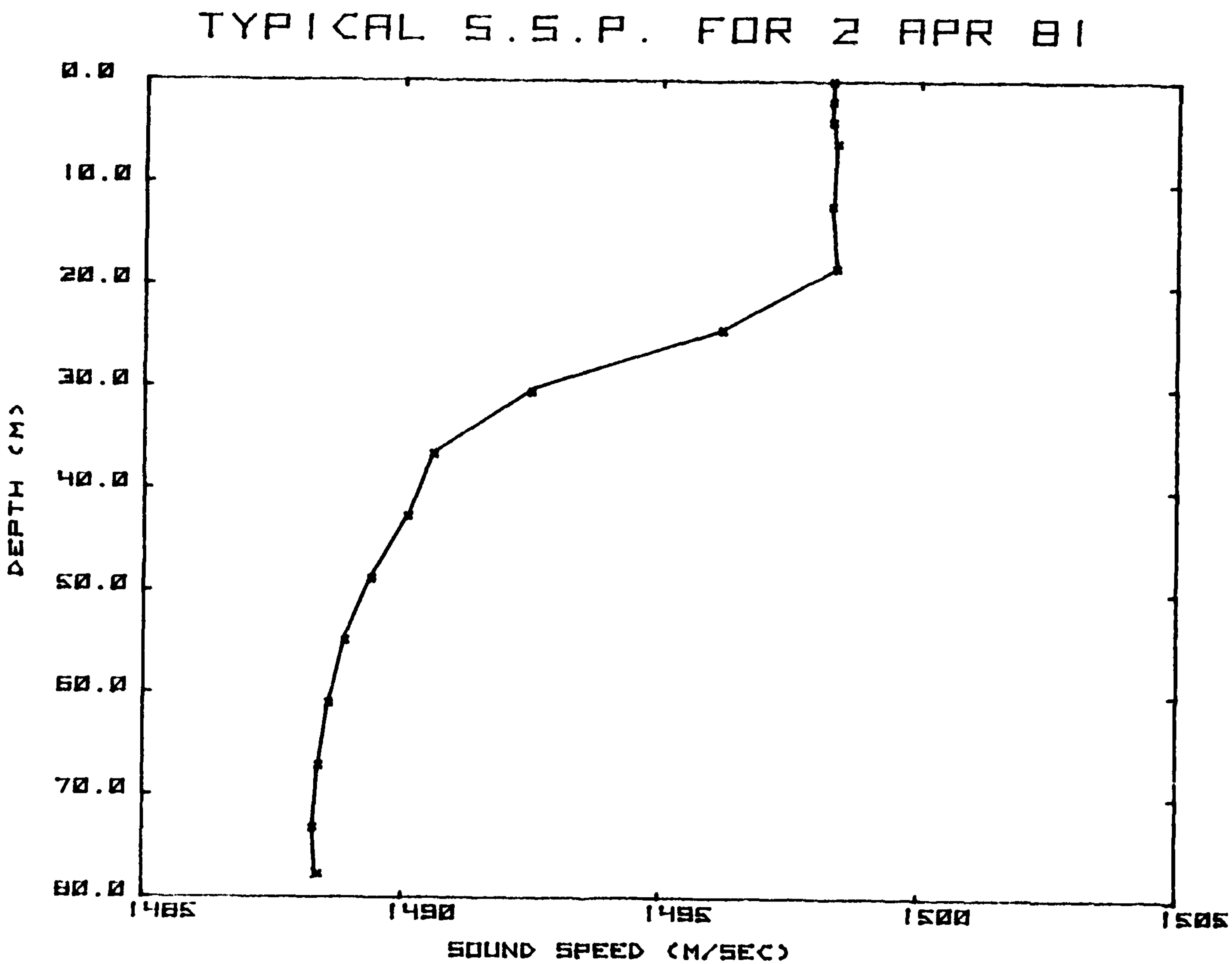

Figure 2.4. Typical Sound Speed Profile for 2 Apr 81 Near Station F.

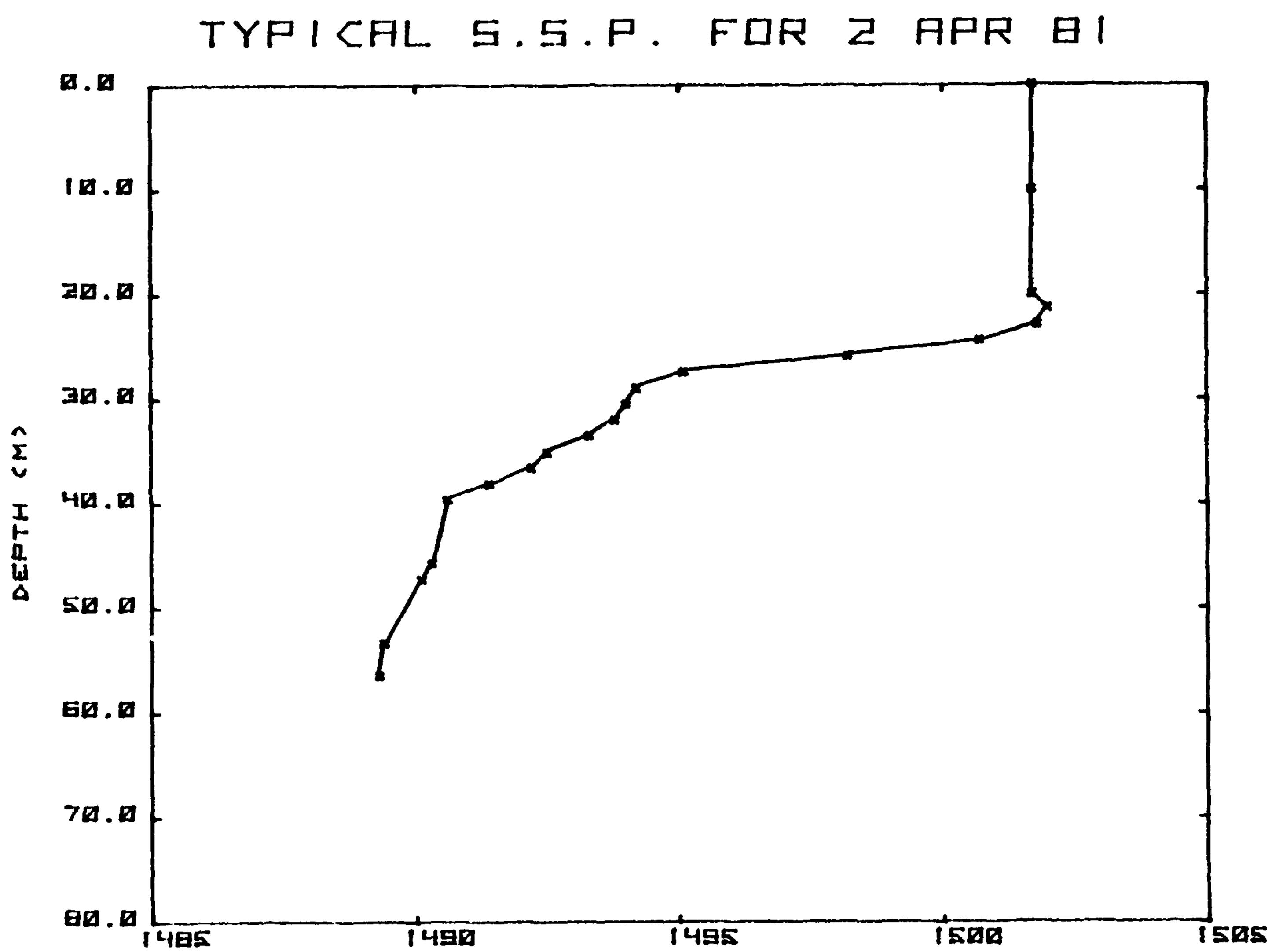

Figure 2.5. Typical Sound Speed Profile for 2 Apr 81 Near Station D.

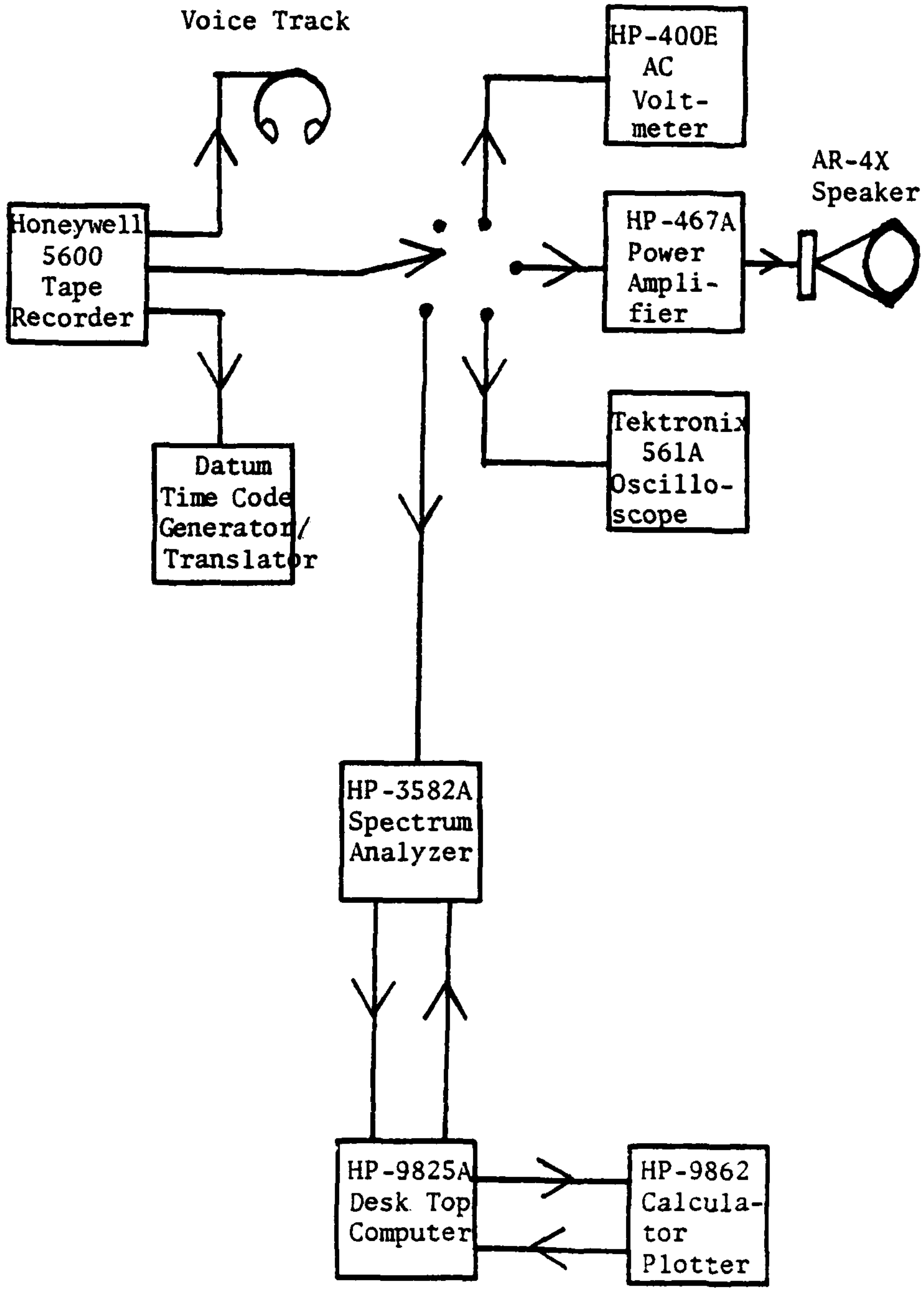

Figure 2.6. Equipment Setup for Data Analysis.

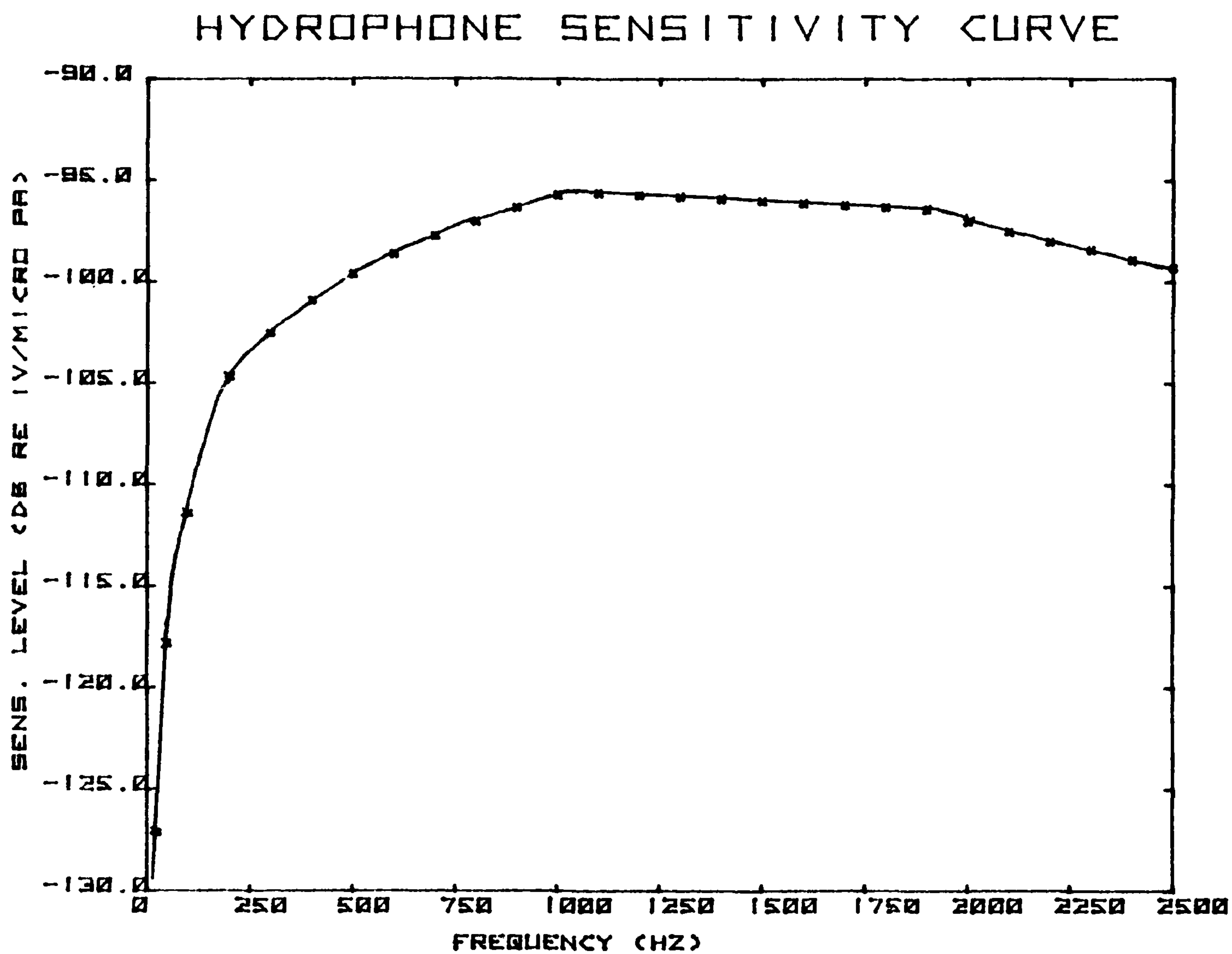

Figure 2.7. Hydrophone Sensitivity Curve Used in Computer Program.

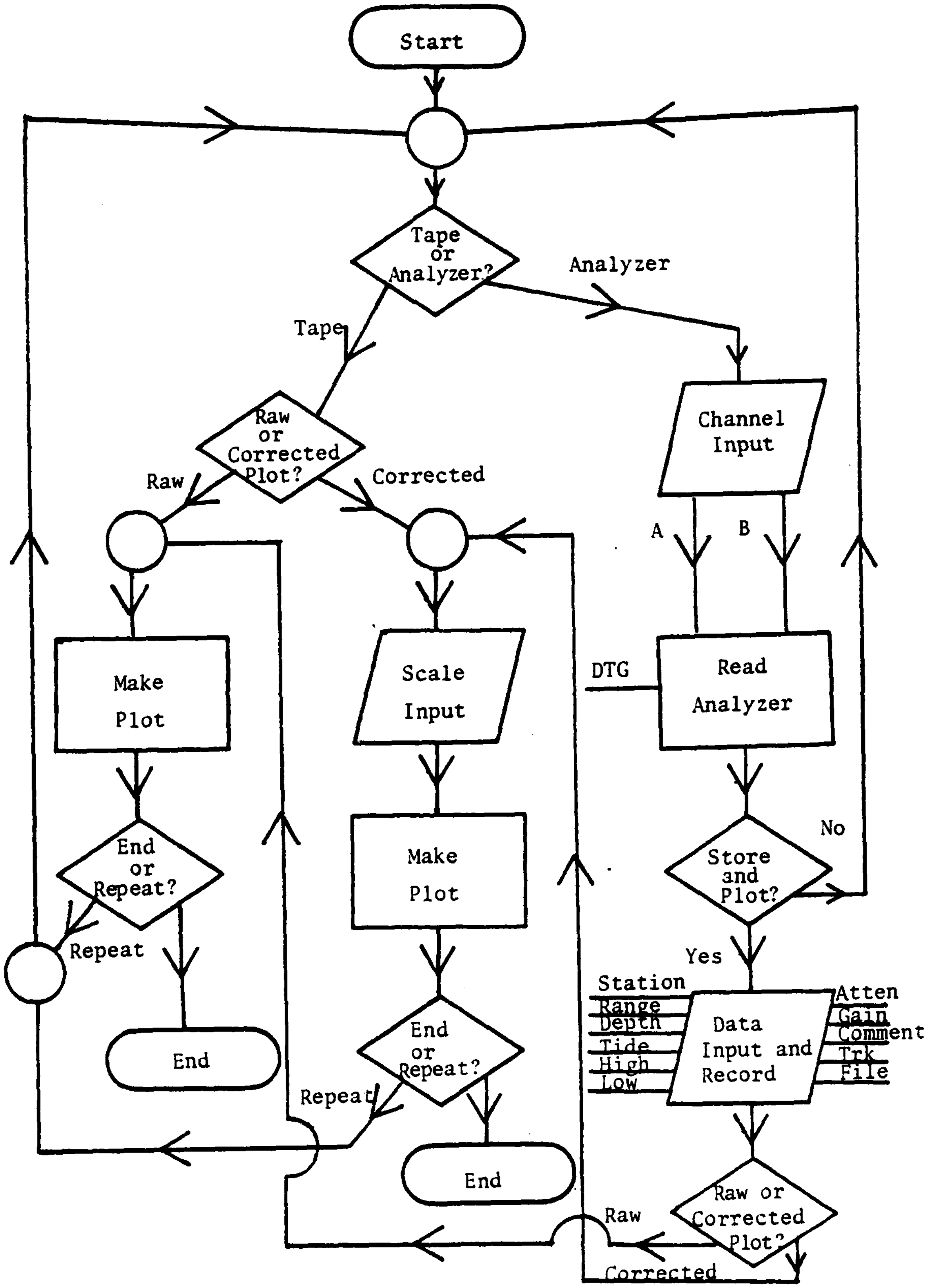

Figure 2.3. Computer Program Flow Diagram.

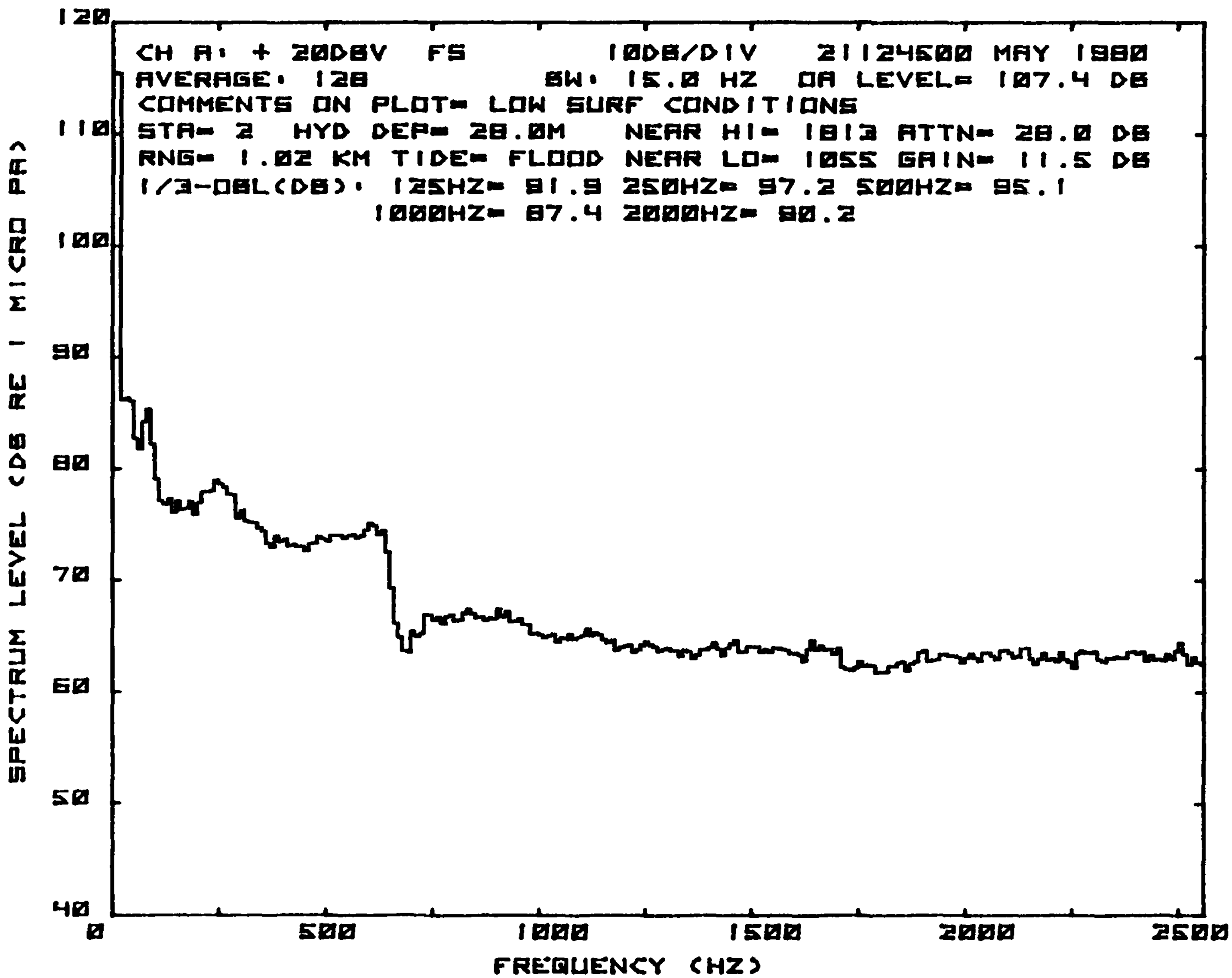

Figure 3.1. Ambient Noise Data at 1245 on 21 May 80 at Station 2 (2.5 kHz Scale) - Low Surf Conditions.

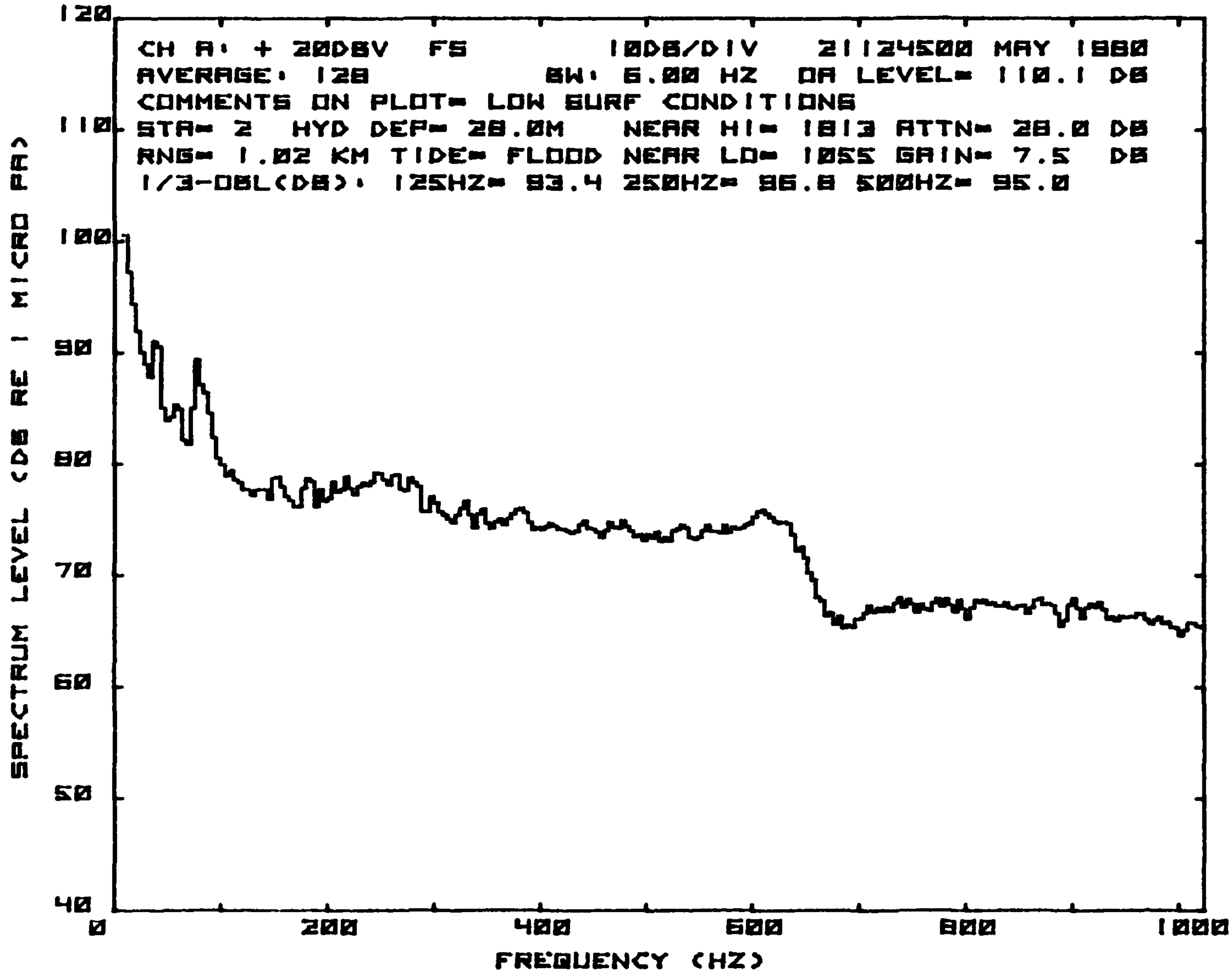

Figure 3.2. Ambient Noise Data at 1245 on 21 May 80 at Station 2 (1.0 kHz Scale) - Low Surf Conditions.

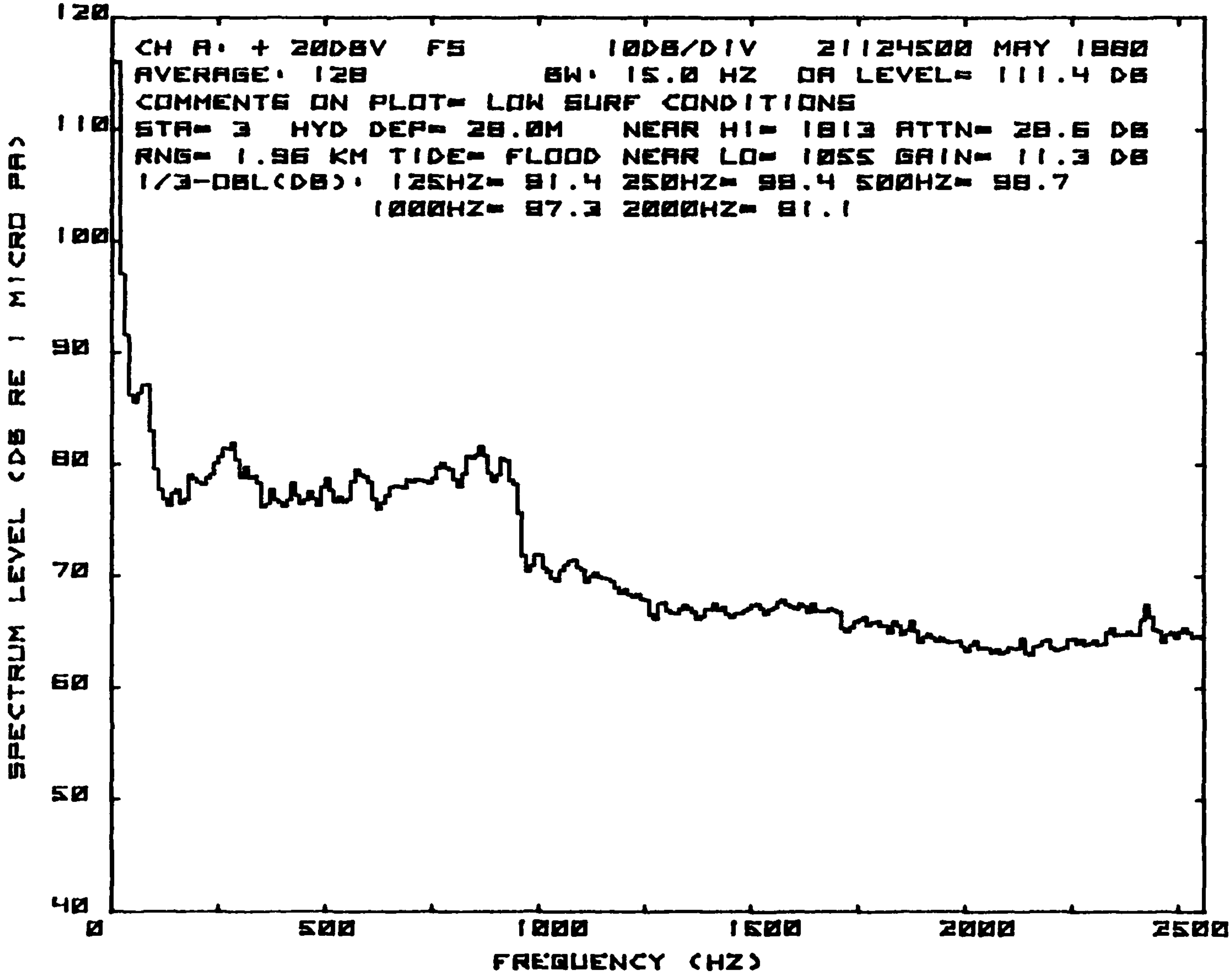

Figure 3.3. Ambient Noise Data at 1245 on 21 May 80 at Station 3 (2.5 kHz Scale) - Low Surf Conditions.

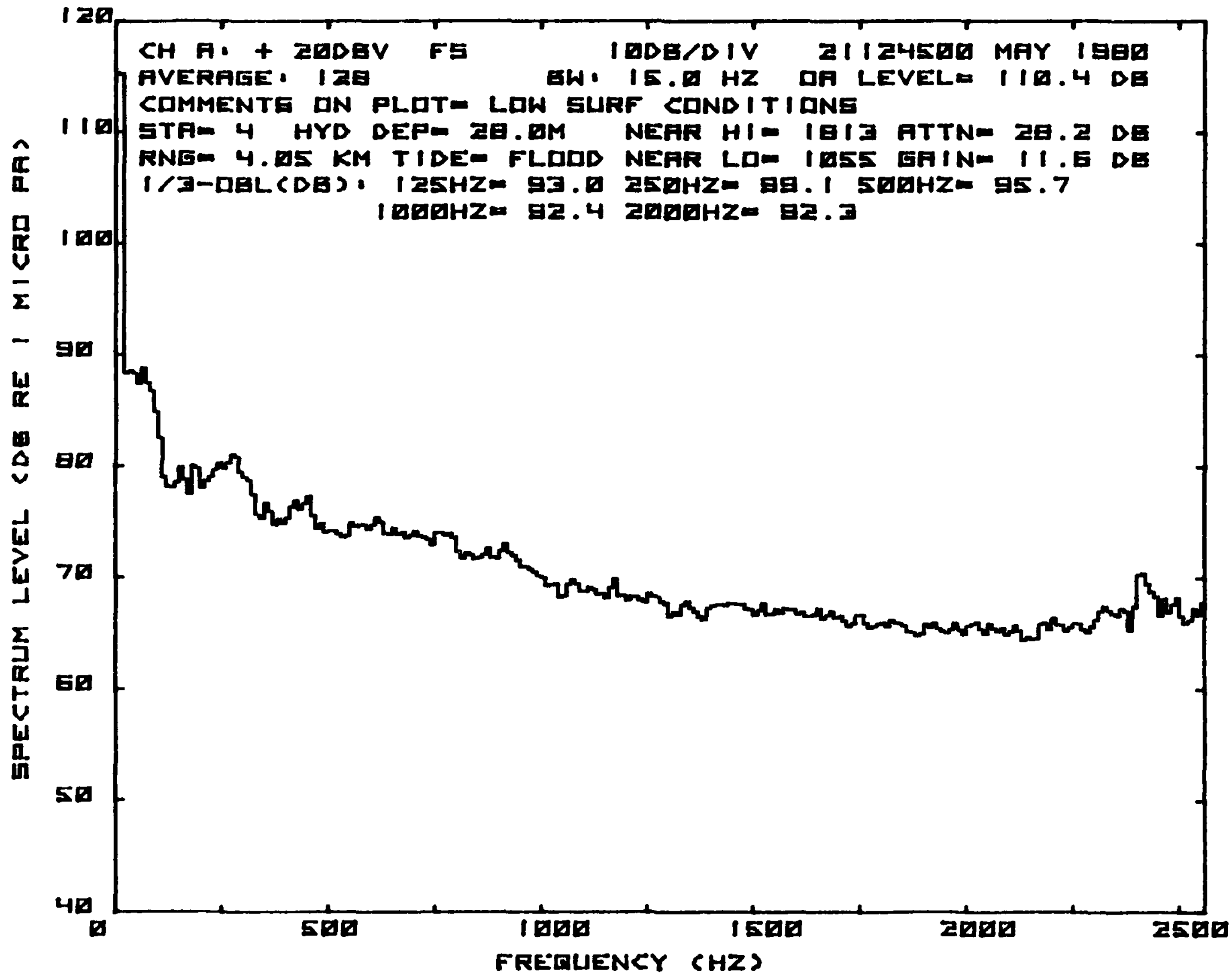

Figure 3.4. Ambient Noise Data at 1245 on 21 May 80 at Station 4 (2.5 kHz Scale) - Low Surf Conditions.

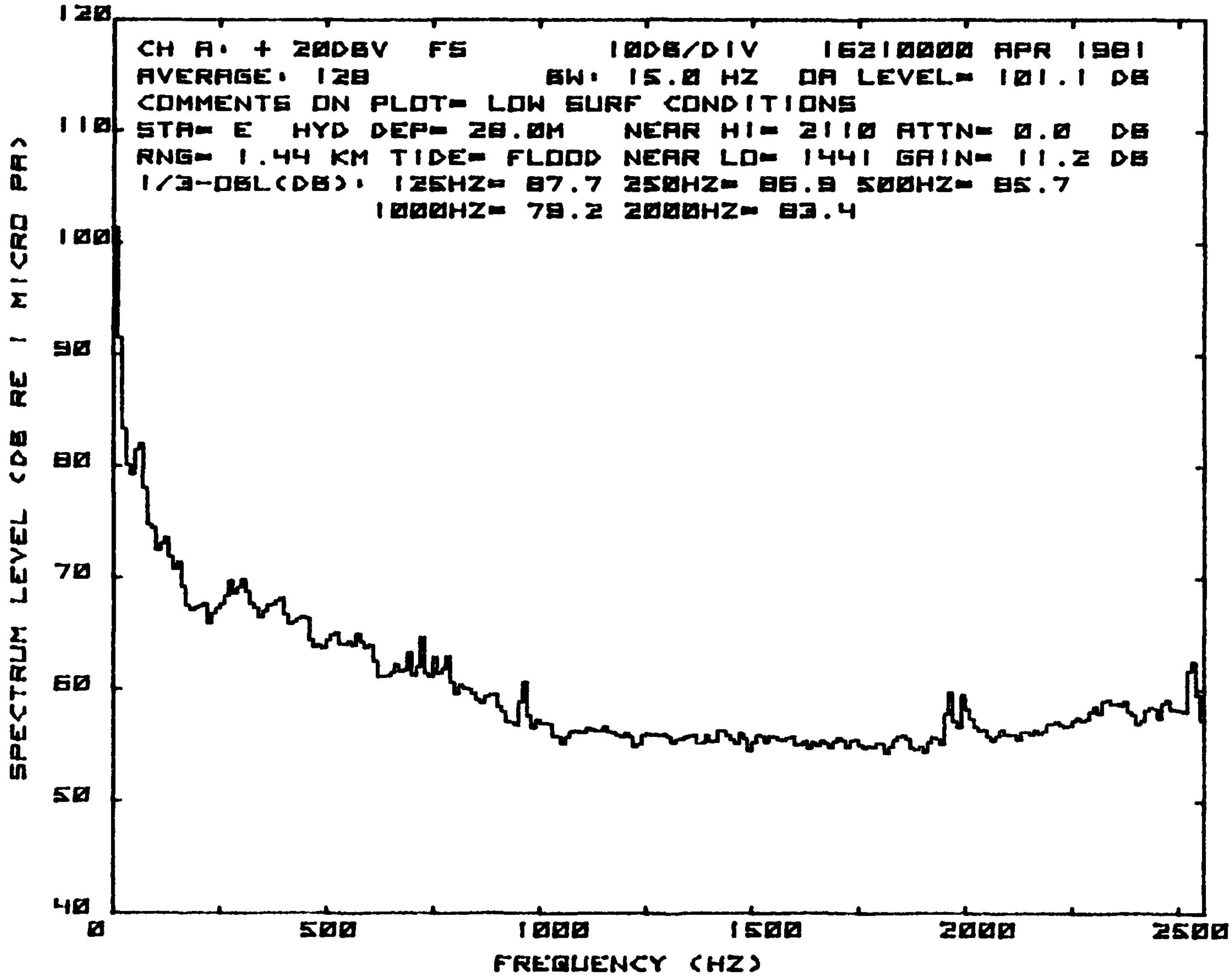

Figure 3.5. Ambient Noise Data at 2100 on 16 Apr 81 at Station E (2.5 kHz Scale) - Low Surf Conditions.

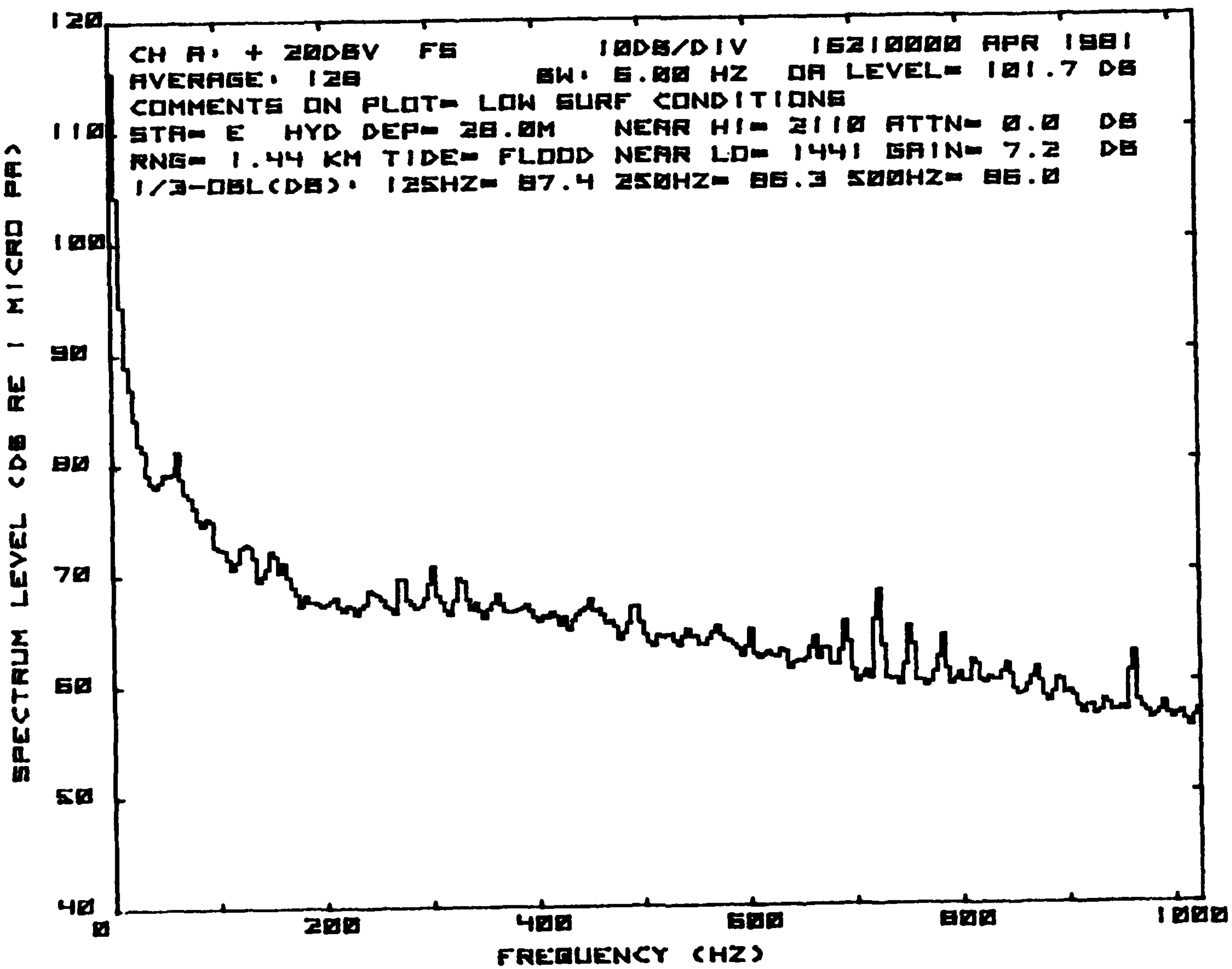

Figure 3.6. Ambient Noise Data at 2100 on 16 Apr 81 at Station E (1.0 kHz Scale) - Low Surf Conditions.

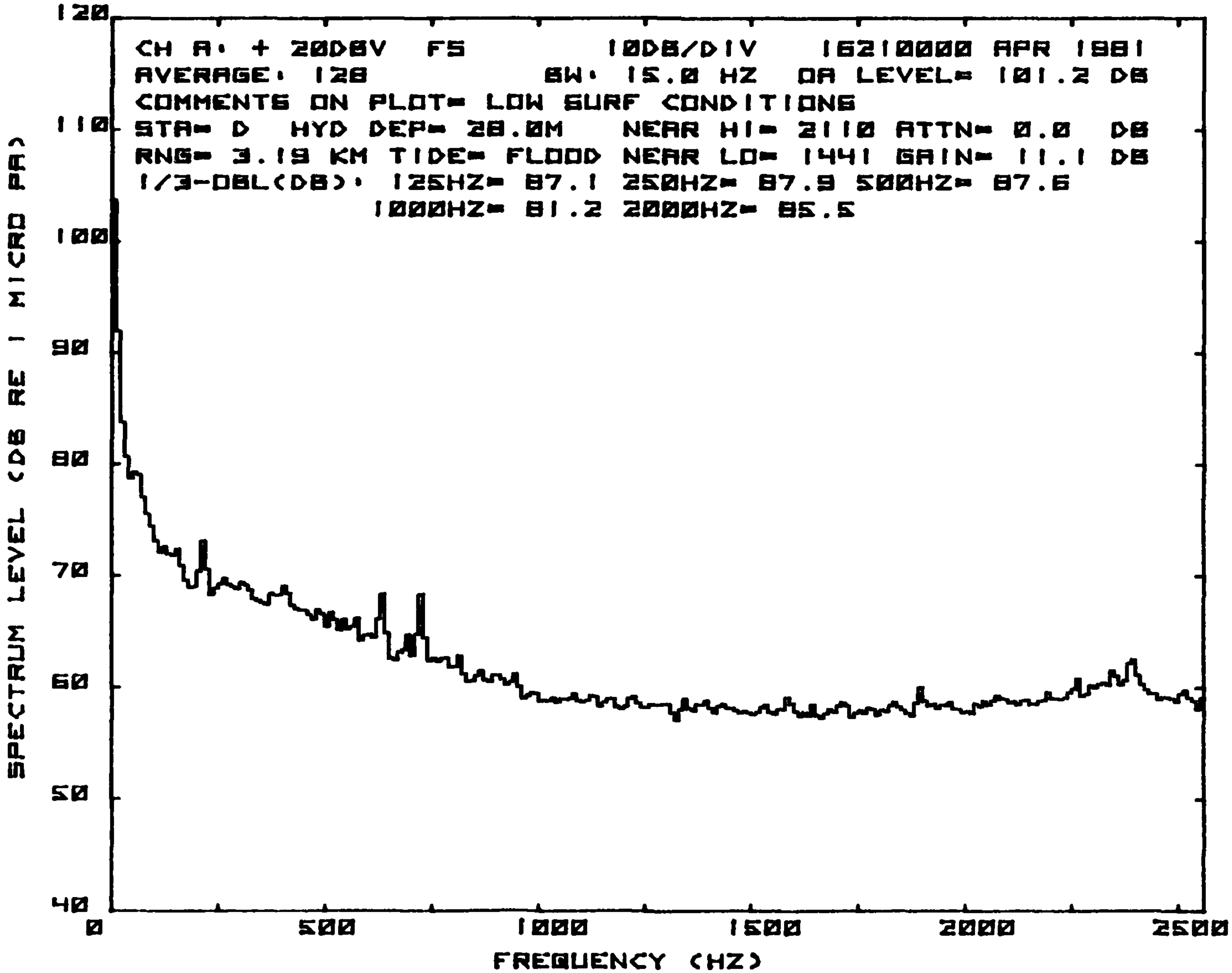

Figure 3.7. Ambient Noise Data at 2100 on 16 Apr 81 at Station D (2.5 kHz Scale) - Low Surf Conditions.

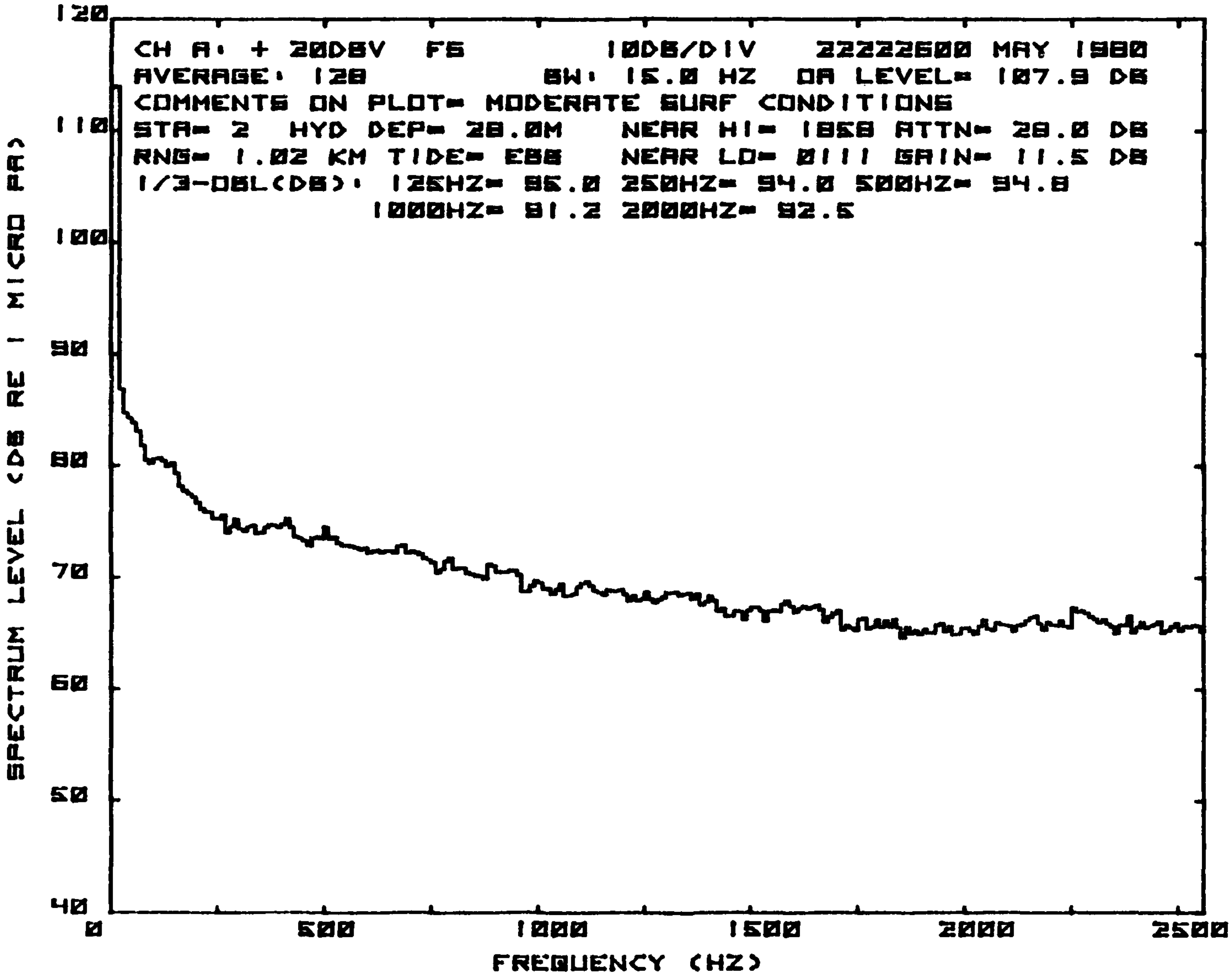

Figure 3.8. Ambient Noise Data at 2226 on 22 May 80 at Station 2 (2.5 kHz Scale) - Moderate Surf Conditions.

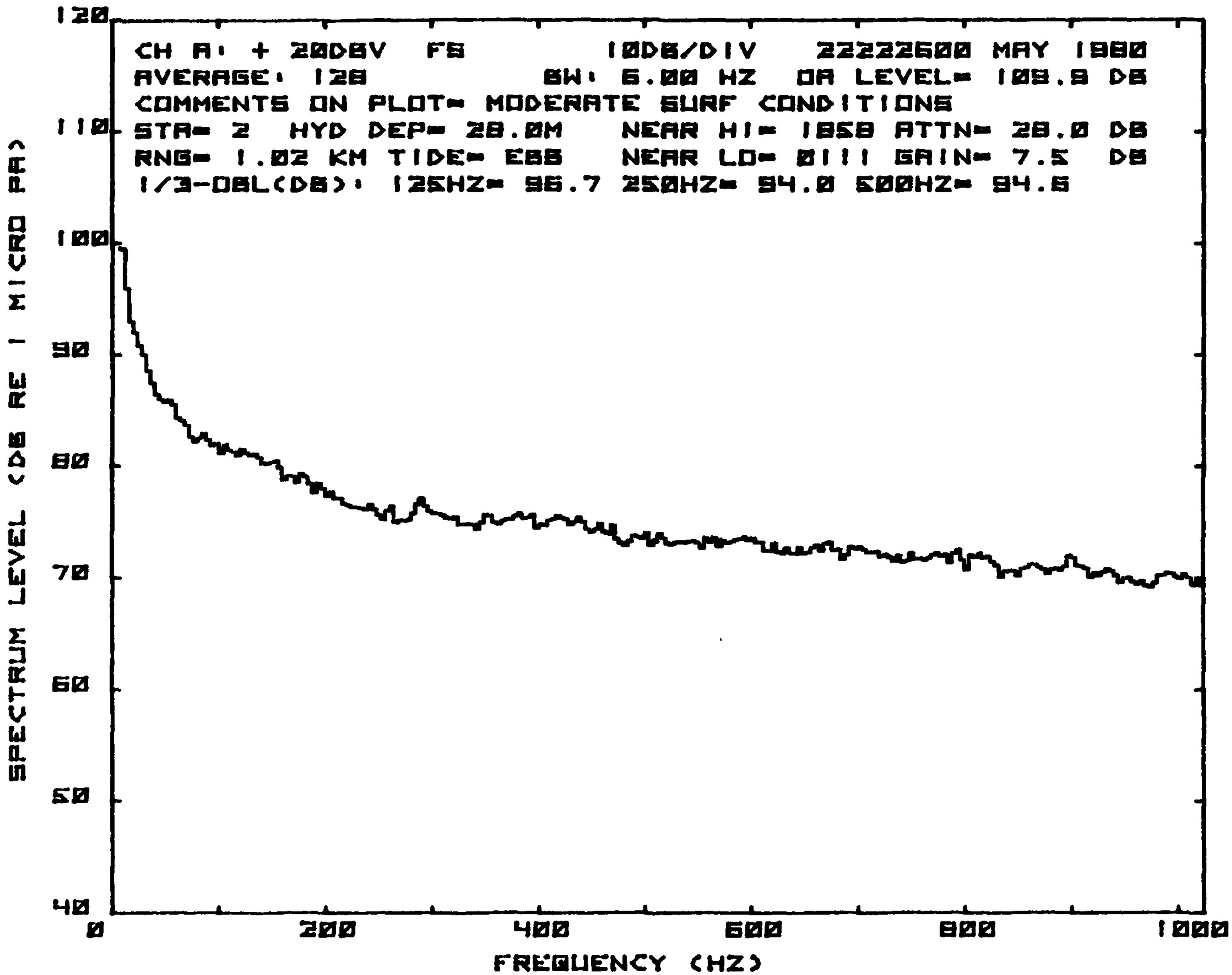

Figure 3.9. Ambient Noise Data at 2226 on 22 May 80 at Station 2 (1.0 kHz Scale) - Moderate Surf Conditions.

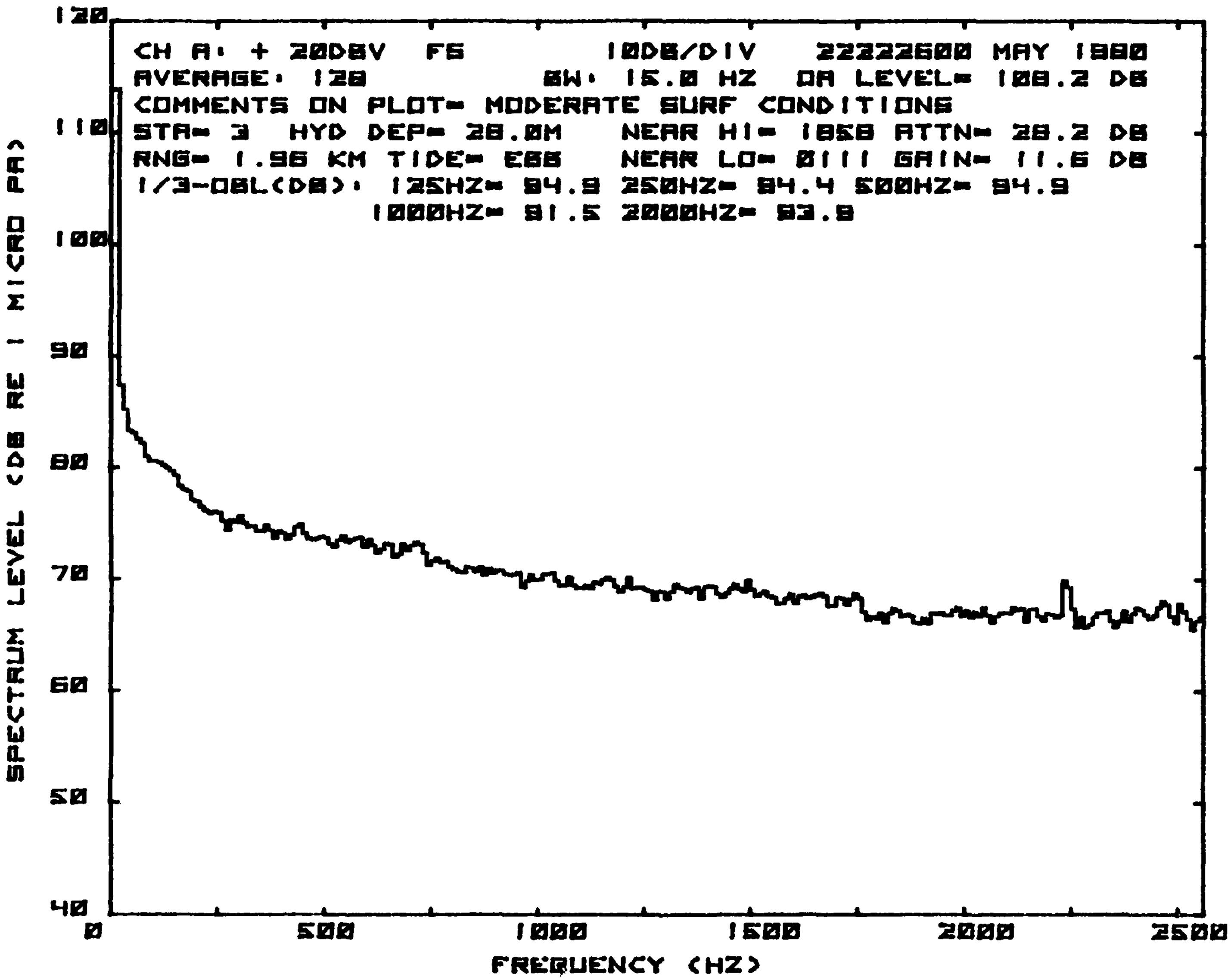

Figure 3.10. Ambient Noise Data at 2226 on 22 May 80 at Station 3 (2.5 kHz Scale) - Moderate Surf Conditions.

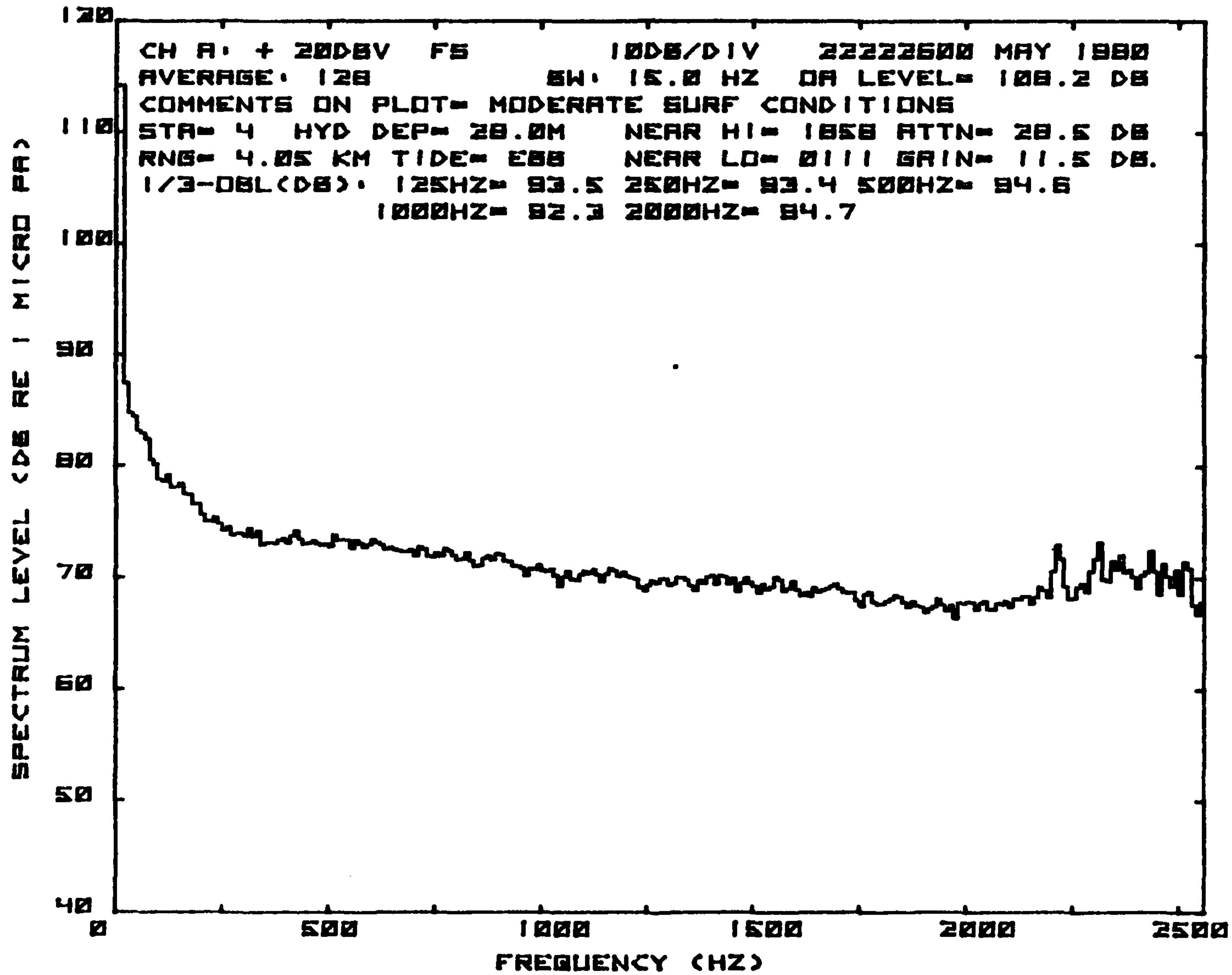

Figure 3.11. Ambient Noise Data at 2226 on 22 May 80 at Station 4 (2.5 kHz Scale) - Moderate Surf Conditions.

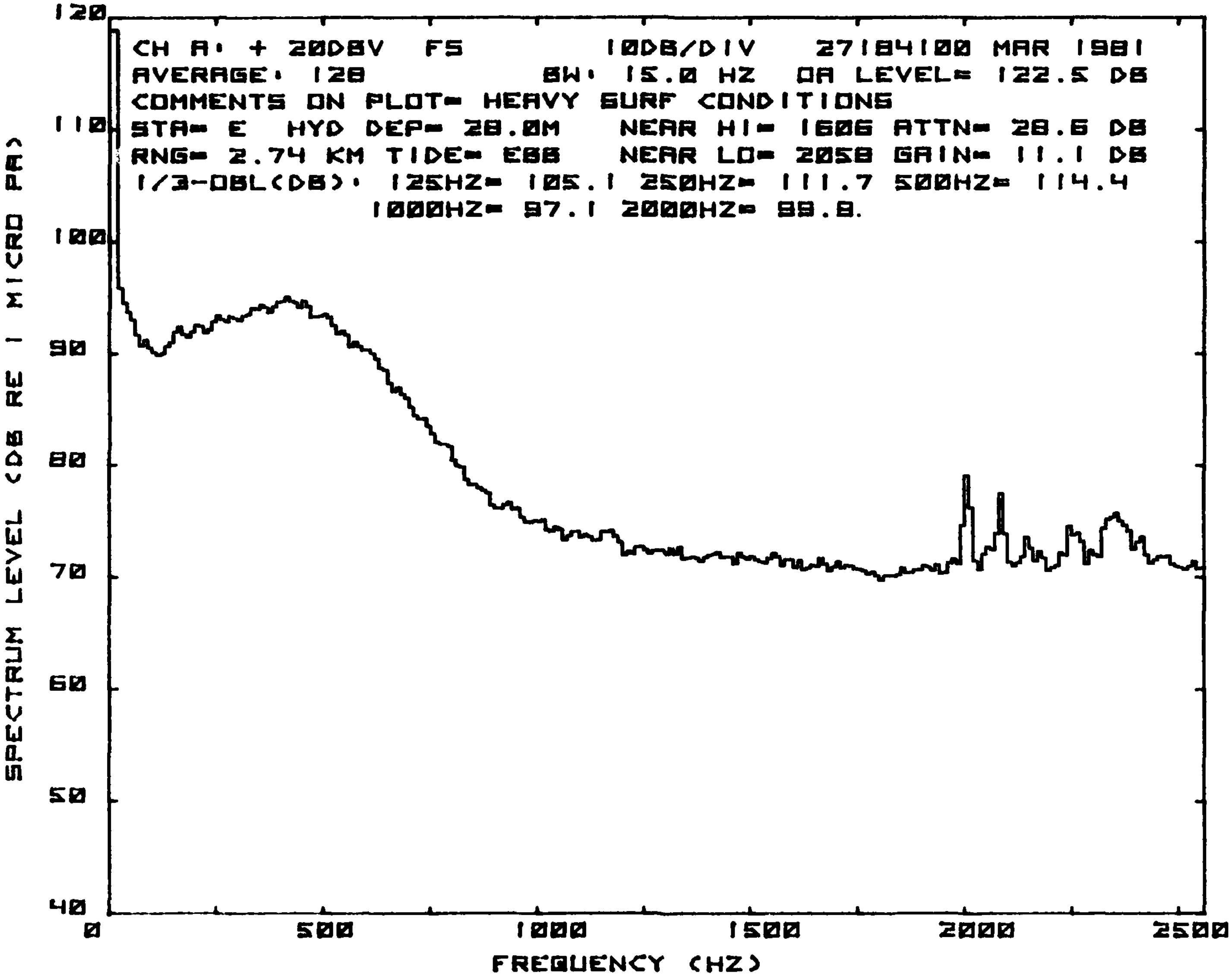

Figure 3.12. Ambient Noise Data at 1841 on 27 Mar 81 at Station E (2.5 kHz Scale) - Heavy Surf Conditions.

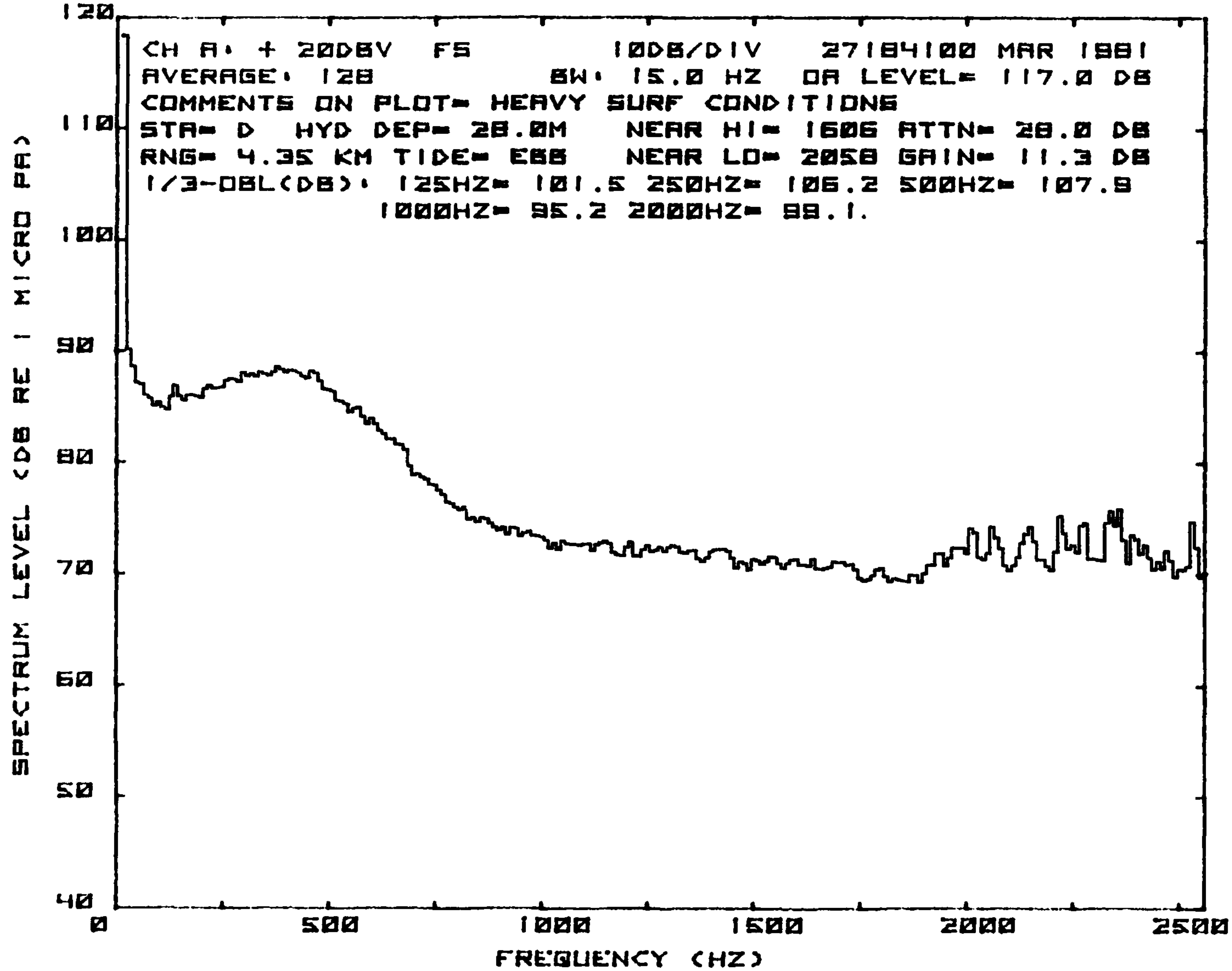

Figure 3.13. Ambient Noise Data at 1841 on 27 Mar 81 at Station D (2.5 kHz Scale) - Heavy Surf Conditions.

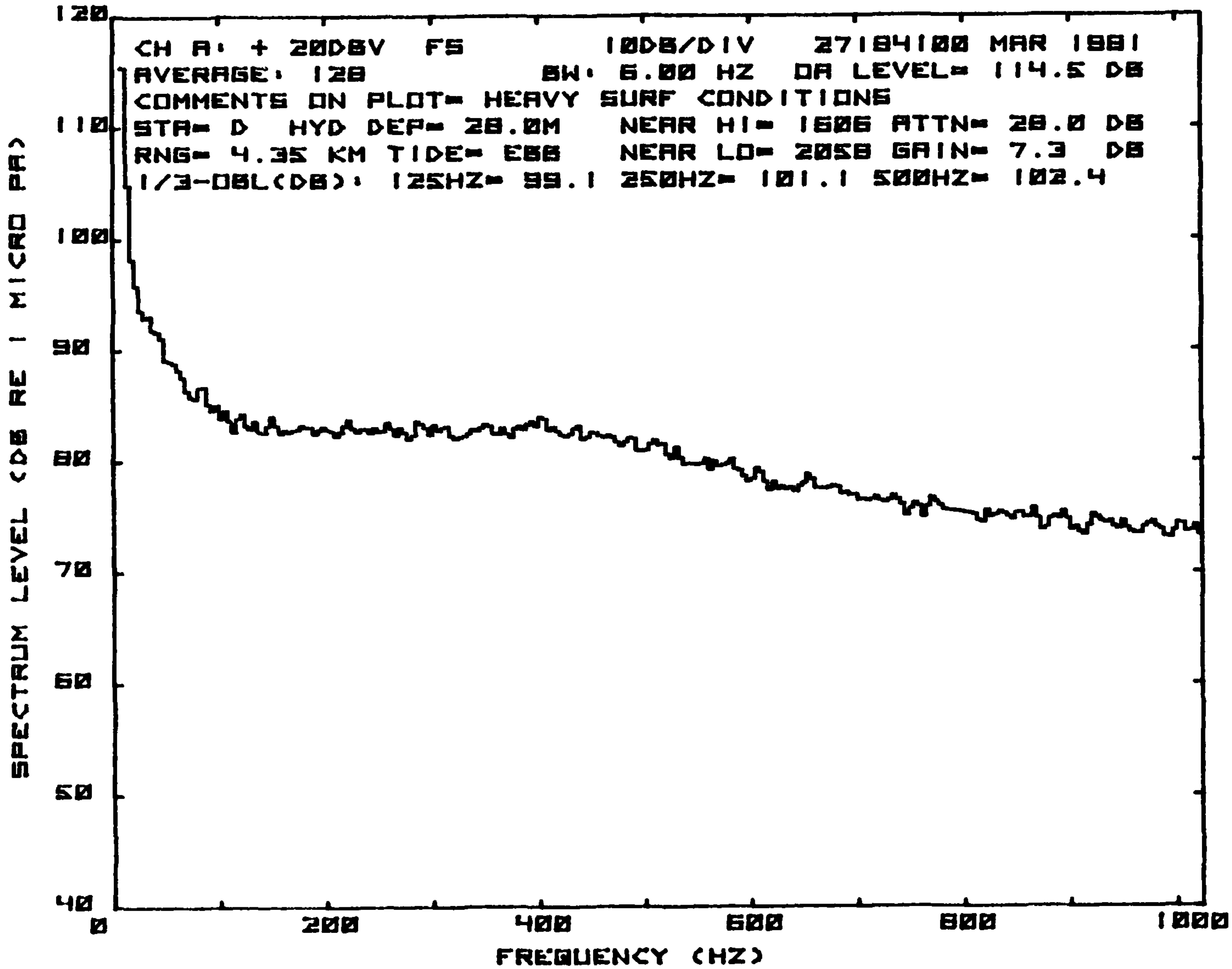

Figure 3.14. Ambient Noise Data at 1841 on 27 Mar 81 at Station D (1.0 kHz Scale) - Heavy Surf Conditions.

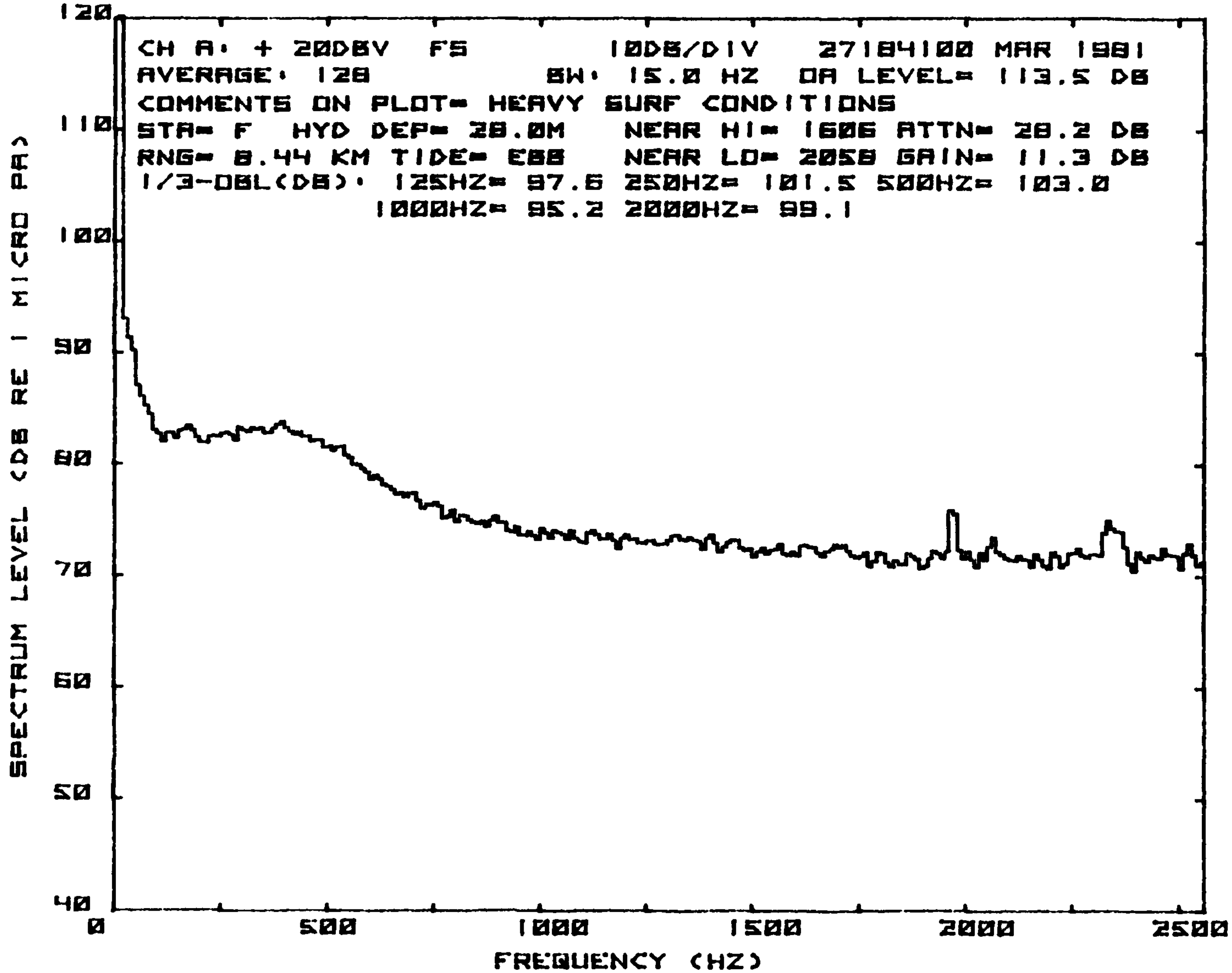

Figure 3.15. Ambient Noise Data at 1841 on 27 Mar 81 at Station F (2.5 kHz Scale) - Heavy Surf Conditions.

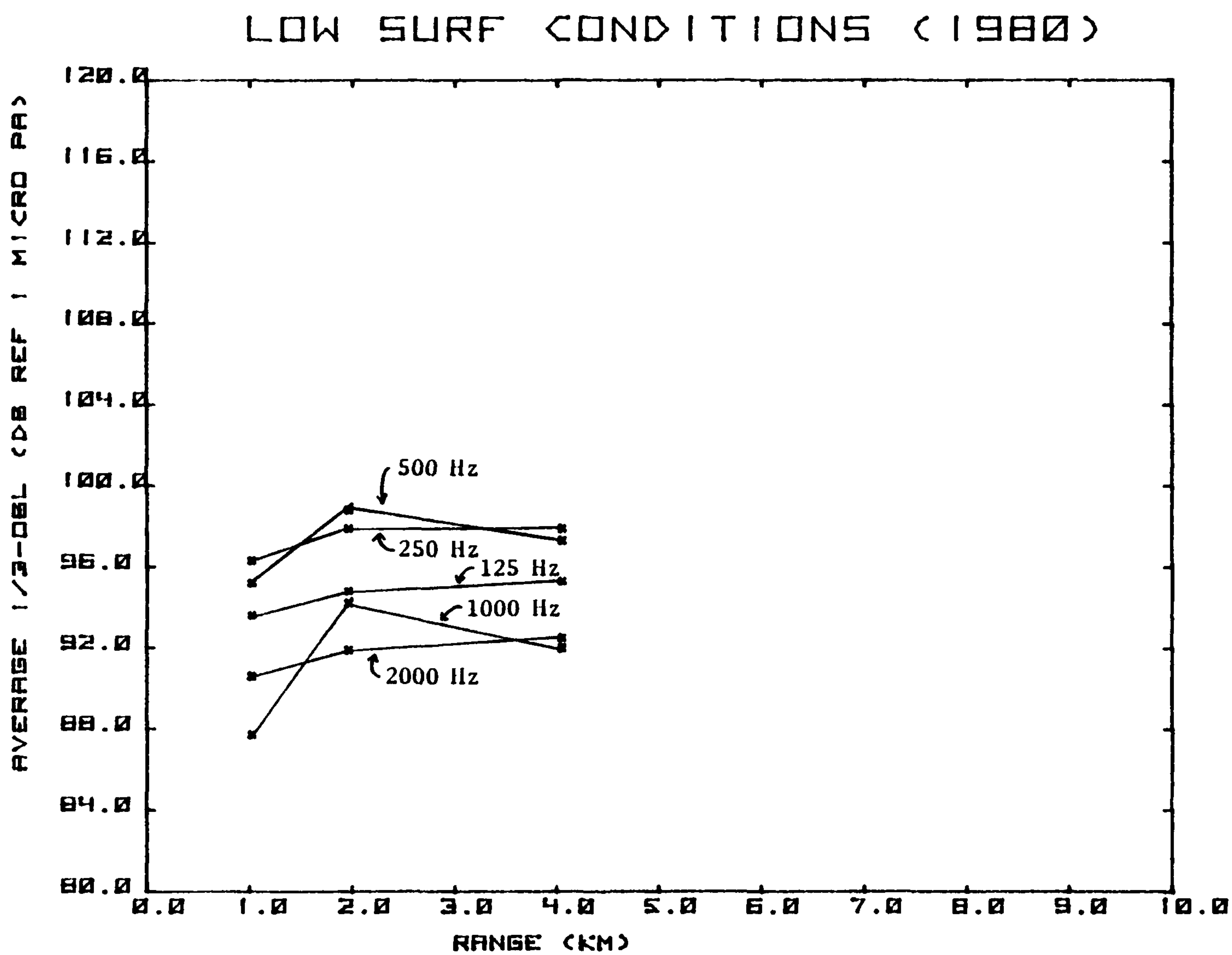

Figure 3.16. Graph of Band Levels for Same Center Frequency Versus Range for Low Surf Conditions (1980).

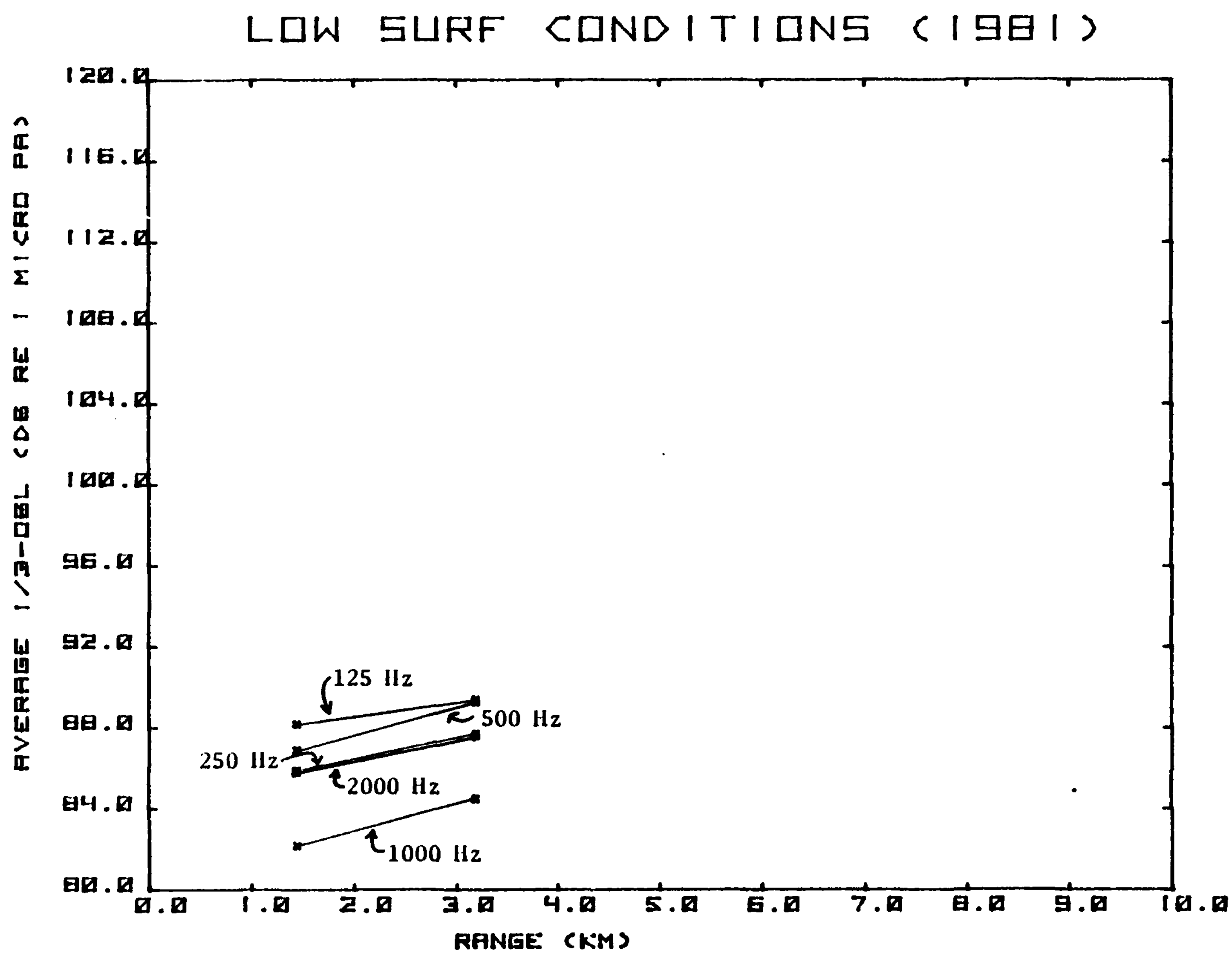

Figure 3.17. Graph of Band Levels for Same Center Frequency Versus Range for Low Surf Conditions (1981).

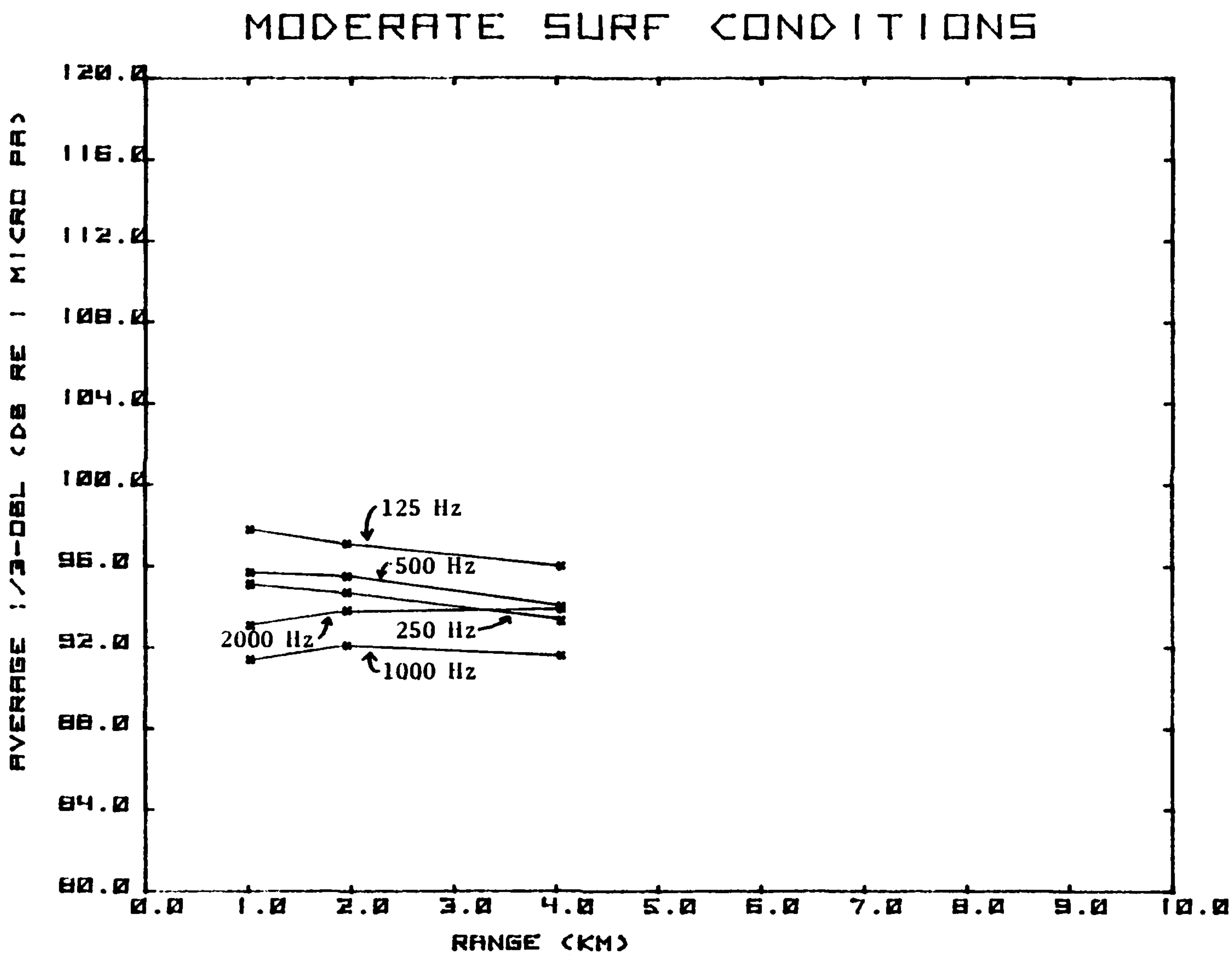

Figure 3.18. Graph of Band Levels for Same Center Frequency Versus Range for Moderate Surf Conditions.

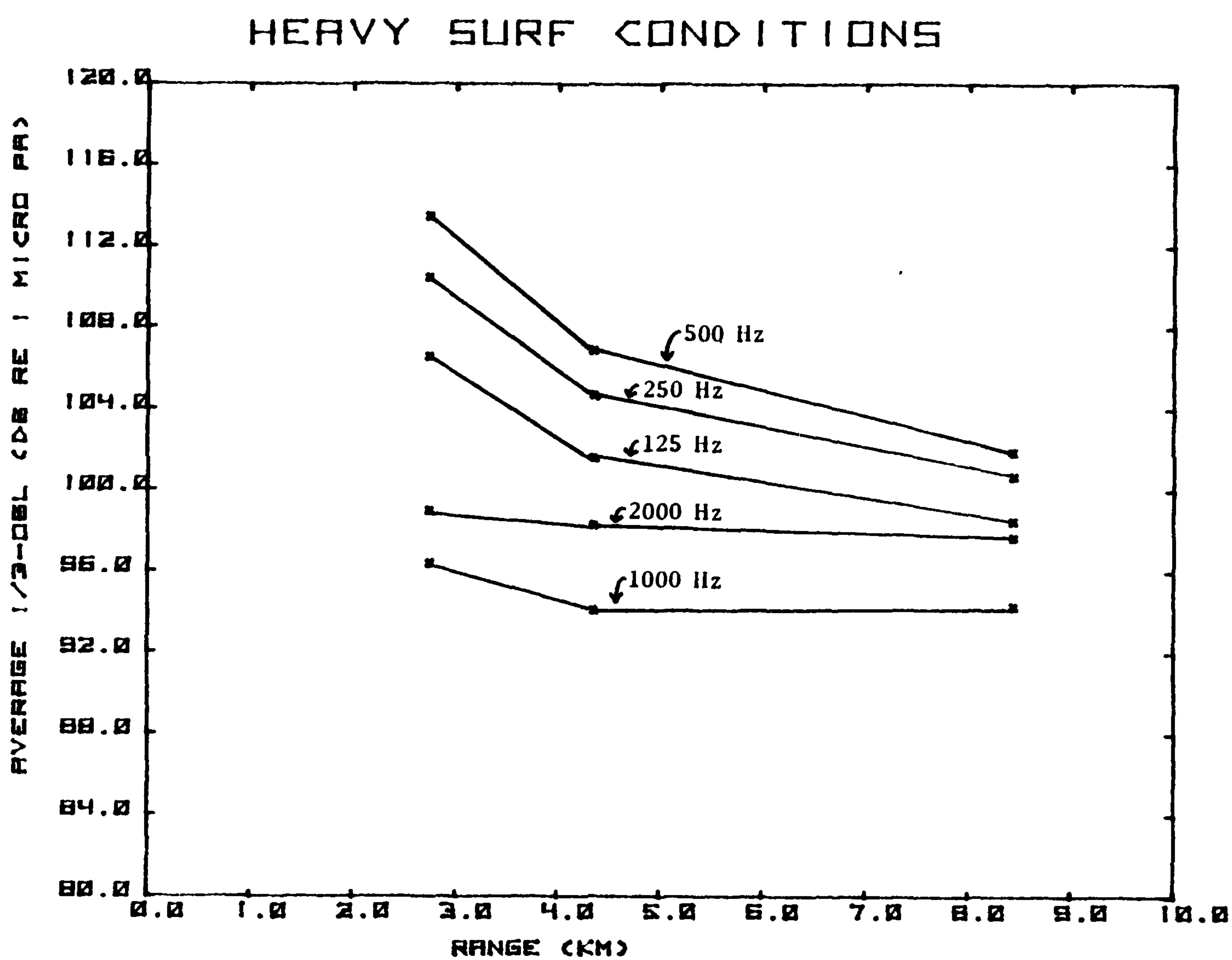

Figure 3.19. Graph of Band Levels for Same Center Frequency Versus Range for Heavy Surf Conditions.

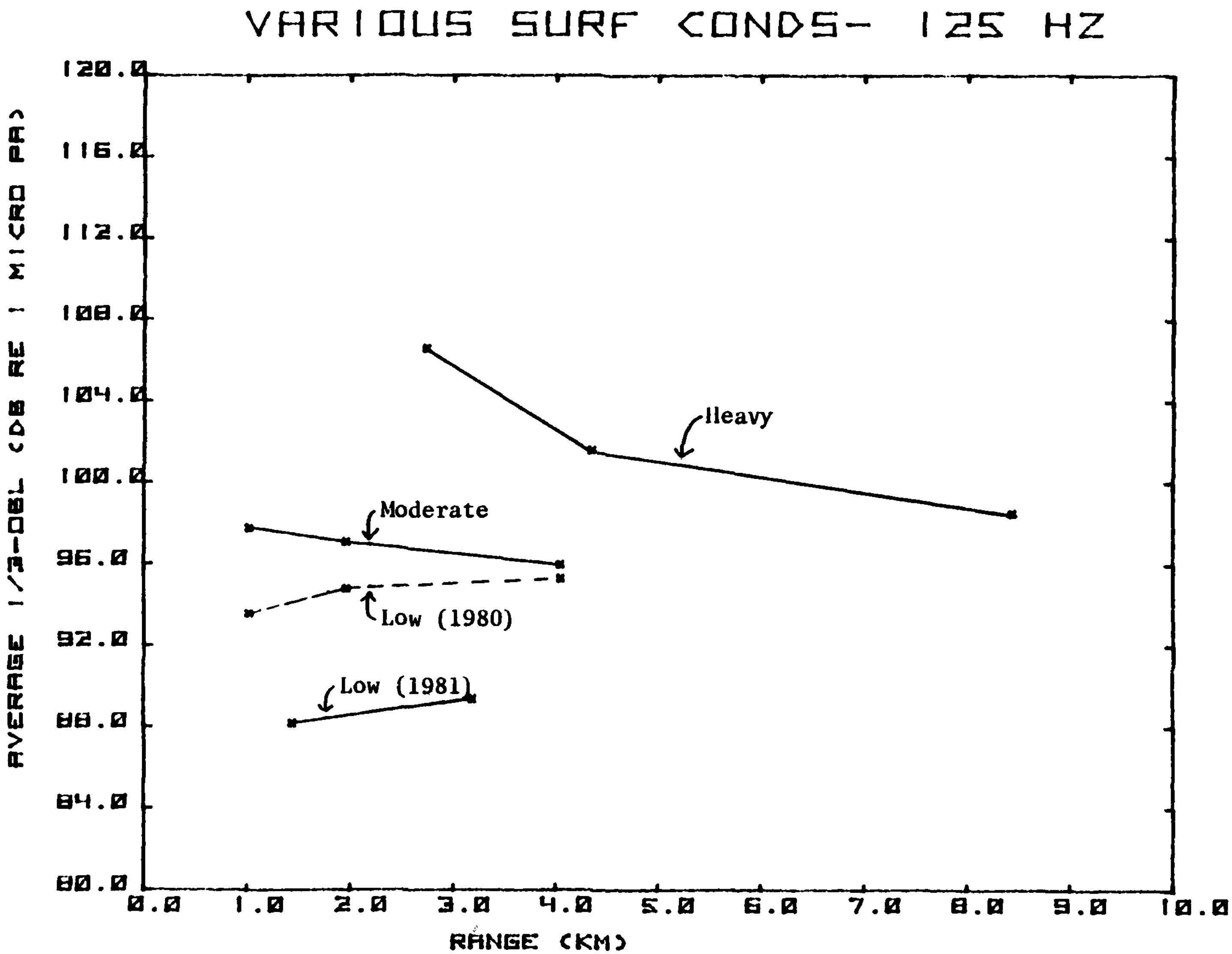

Figure 3.20. Graph of Band Levels for Various Surf Conditions Versus Range for 125 Hz Band.

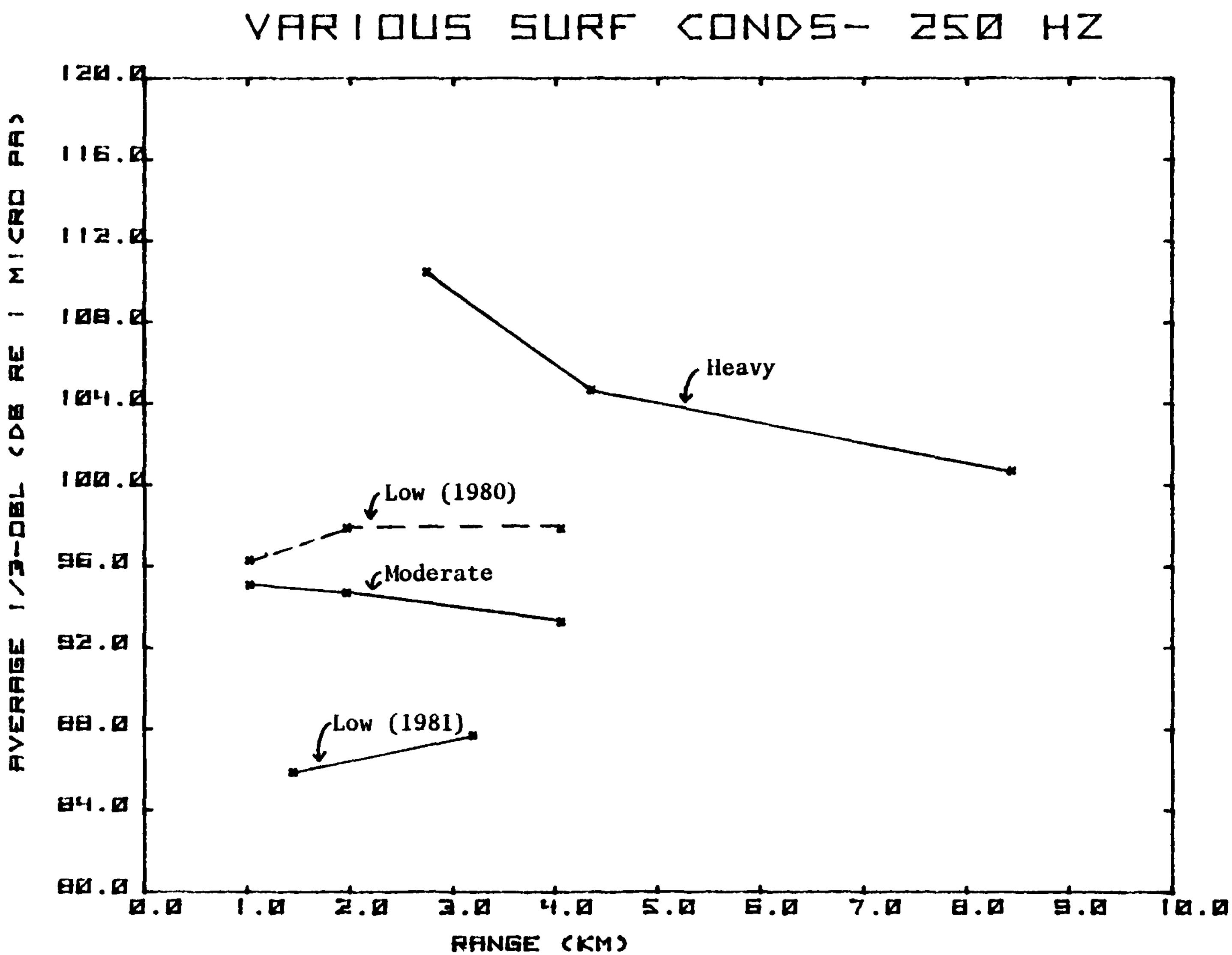

Figure 3.21. Graph of Band Levels for Various Surf Conditions Versus Range for 250 Hz Band.

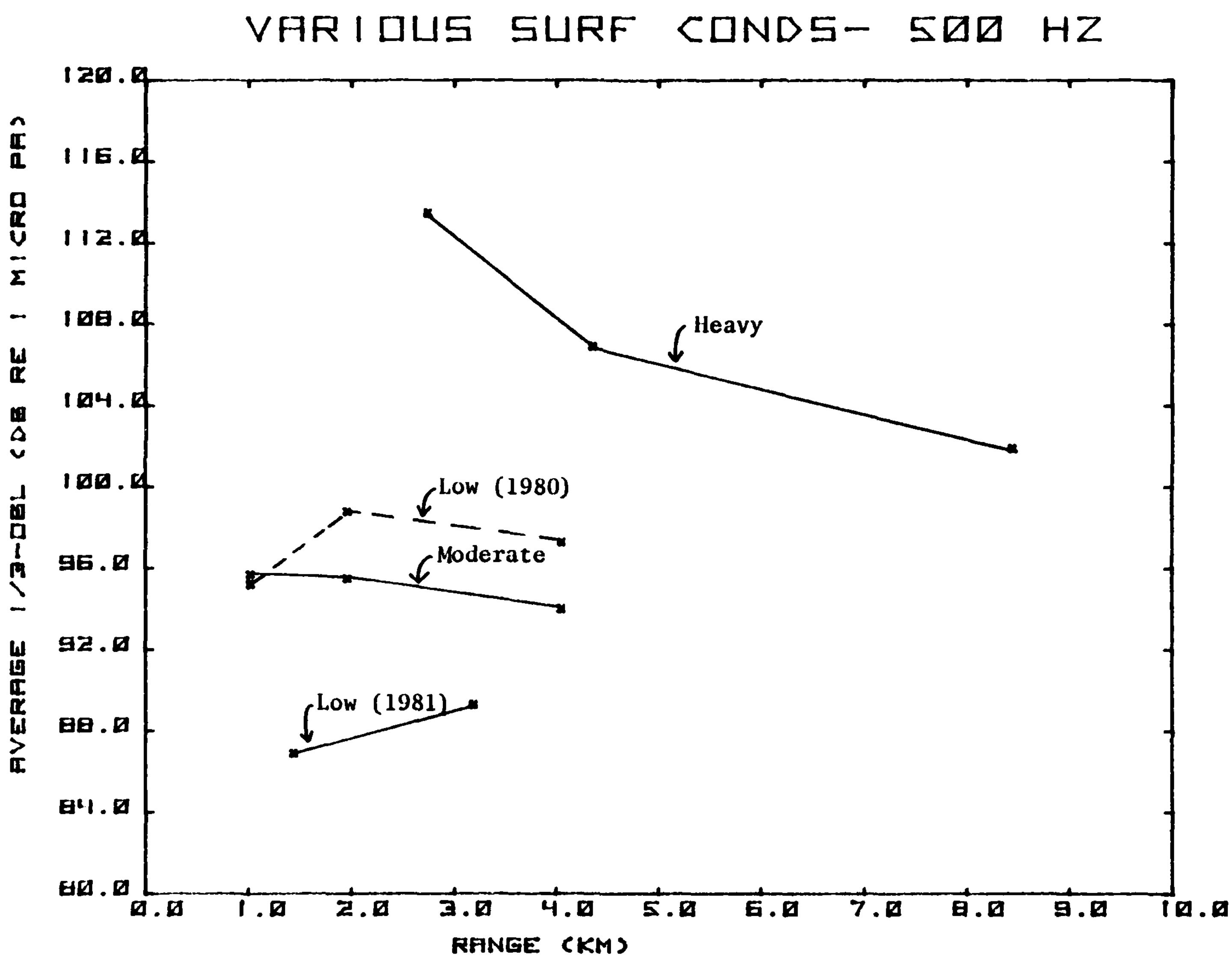

Figure 3.22. Graph of Band Levels for Various Surf Conditions Versus Range for 500 Hz Band.

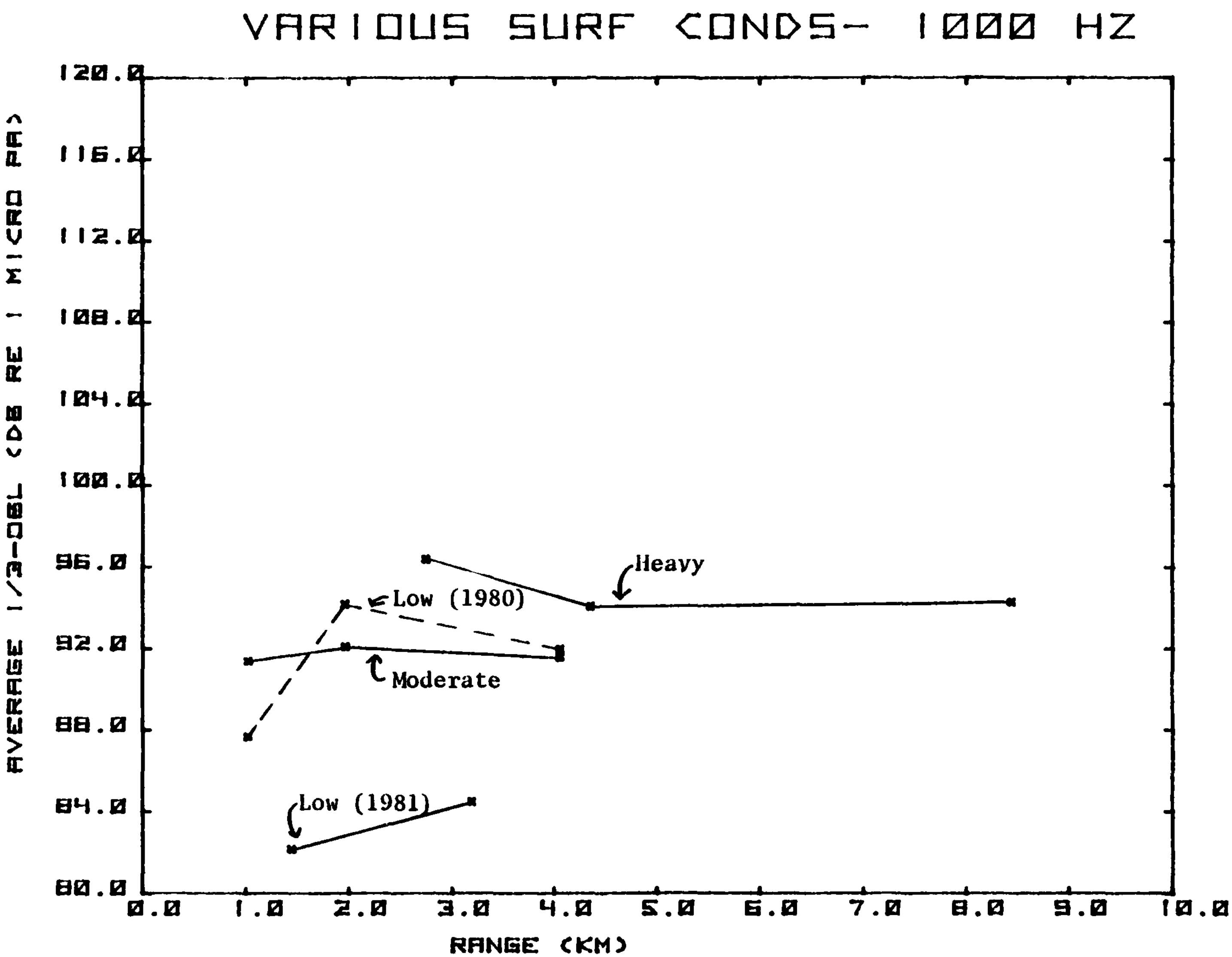

Figure 3.23. Graph of Band Levels for Various Surf Conditions Versus Range for 1000 Hz Band.

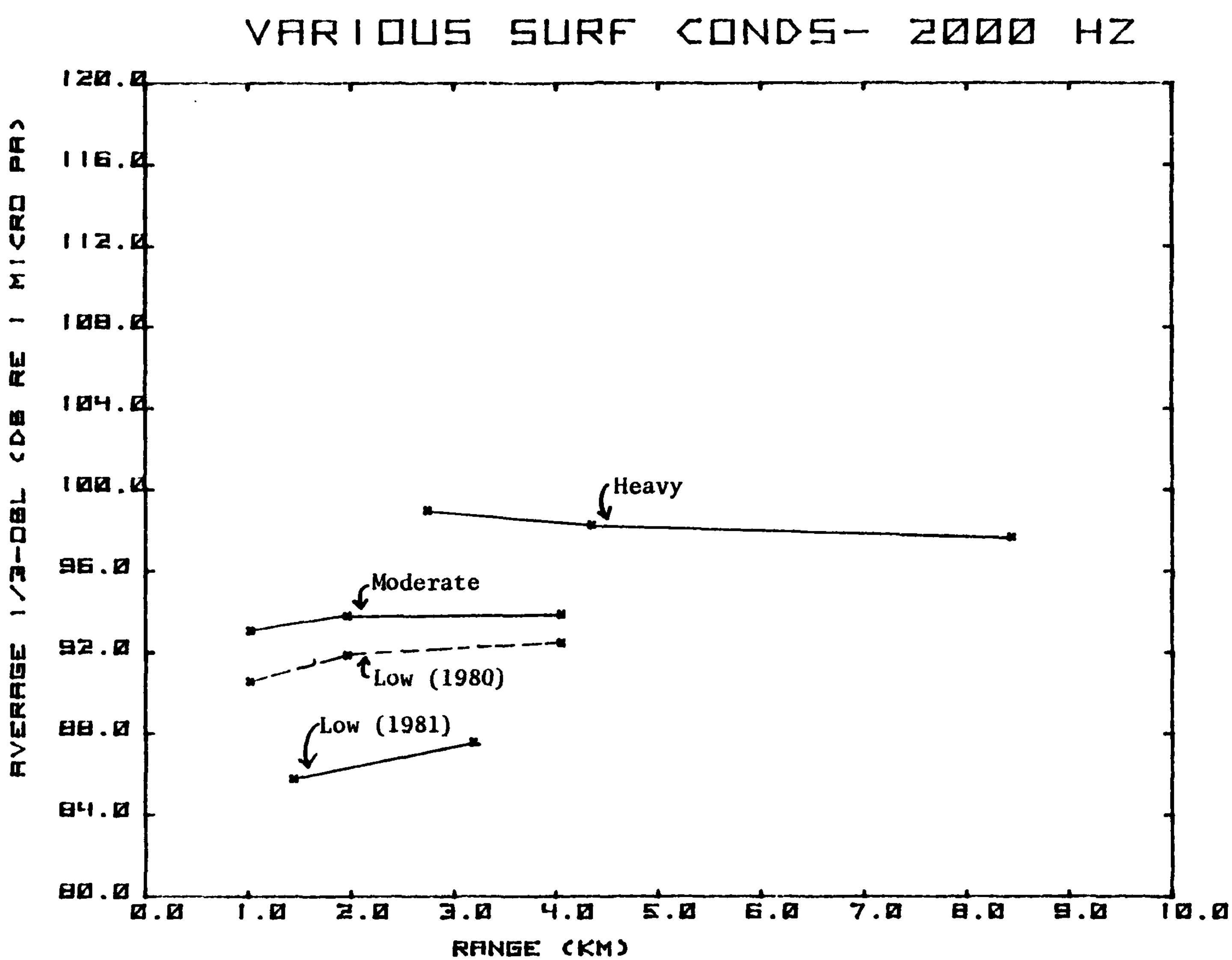

Figure 3.24. Graph of Band Levels for Various Surf Conditions Versus Range for 2000 Hz Band.

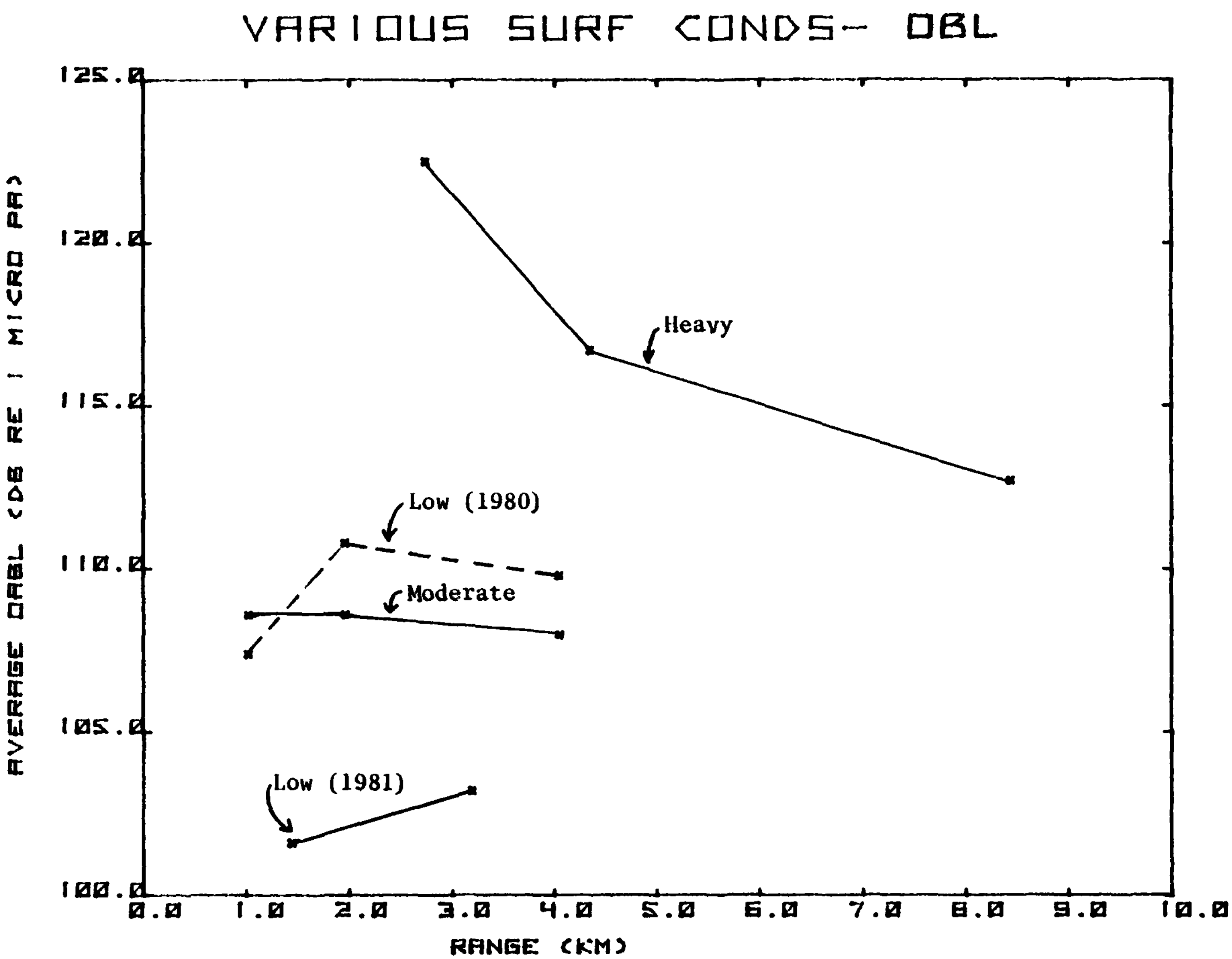

Figure 3.25. Graph of Overall Band Levels for Various Surf Conditions (From 2.5 kHz Scale) Versus Range.

APPENDIX A

COMPUTER PROGRAM

```
 0:  "Program to plot surf noise spectrum allowing for":
 1:  "system response corrections":
 2:  dim A[256], B[256], C$[128], I$[20], D$[60], W$[34] ,B,D
 3:  dim G[256], P[256]
 4:  dsp "If you see"*""-press""CONTINUE"" *";beep;stp
 5:  dsp "HP3582A plot or tape plot?    *";beep;stp
 6:  ent "Set 0= HP3582A or 1= tape",r0;beep
 7:  if r0=0;jmp 6
 8:  ent "What track has data?",Q;beep
 9:  ent "What file has data?",R;beep
10:  trk Q
11:  ldf R,A[*],B[*],C$,I$,D$,W$,B,D
12:  gto 49
13:  ent "Channel A or B? Set 0=A or 1=B",r1;beep
14:  ent "DTG data spectrum started=?",I$;beep
15:  wrt 711,"LSP"
16:  red 711,D
17:  if r1=1;jmp 4
18:  wrt 711,"LAS"
19:  red 711,B
20:  jmp 3
21:  wrt 711,"LBS"
22:  red 711,B
23:  wrt 711,"LAN"
24:  red 711,C$
25:  wrt 711,"LDS"
26:  red 711
27:  for I=1 to 256
28:  red 731,A[I]
29:  next I
30:  dsp "Want to store and plot data?  *";stp ;beep
31:  ent "Decide! Enter 0=No or 1=Yes",r2;beep
32:  if r2=0;gto 4
33:  ent "Station number =? ,W$[1,3];beep
34:  ent "Range from beach (km) =?",W$[4,7];beep
35:  ent "Hydrophone depth (meters) =?",W$[8,11];beep
36:  ent "Current tide =?",W$[12,16];beep
37:  ent "Nearest high tide time=?,W$[17,20];beep
38:  ent "Nearest low tide time =?",W$[21,24];beep
39:  ent "Attenuation required (dB) =?",W$[25,29];beep
40:  ent "Instrument gain noted (dB) =?",W$[30,34];beep
41:  ent "Comments for this plot =?",D$;beep
42:  ent "Data to be stored on track =?",T;beep
43:  ent "Data to be stored on file =?",F;beep
44:  trk T
45:  rcf F,A[*],B[*],C$,I$,D$,W$,B,D
```

```
46:  dsp "Make sure paper in plotter!   *";stp ;beep
47:  trk T
48:  ldf F,A[*],B[*],C$,I$,D$,W$,B,D
49:  dsp "Want a plot of raw data?       *";stp ;beep
50:  ent "Raw data plot? 0=No or 1=Yes",r4;beep
51:  if r4=0;jmp 7
52:  B→U
53:  B-80→L
54:  8→M
55:  10→N
56:  gsb "Sub 1"
57:  gsb "Sub 2"
58:  dsp "Now a plot with sys response? *";beep;stp
59:  dsp "If you are- check your paper! *";beep;stp
60:  ent "Corrected plot?  0=No or 1=Yes",r5;beep
61:  if r5=0;gto 4
62:  B+100→U
63:  B+20→L
64:  8→M
65:  10→N
66:  dsp "Scale? 500, 1000, or 2500Hz?  *";beep;stp
67:  ent "Set 0= 500, 1=1000, or 2=2500Hz",r6;beep
68:  gsb "Sub 1"
69:  if r6=0;gsb "Sub 3"
70:  if r6=1;gsb "Sub 4"
71:  if r6=2;gsb "Sub 5"
72:  gsb "Sub 6"
73:  if r6=0;gsb "Sub 7"
74:  if r6=1;gsb "Sub 8"
75:  if r6=2;gsb "Sub 9"
76:  dsp "Plot'sdone- whatcha think?    *";beep;stp
77:  dsp "Hit""CONTINUE""if doing more!";beep;stp
78:  lcl 711
79:  gto 4
80:  end
81:  "Sub 1":
82:  scl -25,280,L-6,U+2
83:  plt 0,L,1
84:  for I=1 to 10
85:  plt 25I,L,2
86:  plt 25I,L+(U-L)/150,2
87:  plt 25I,L,2
88:  next I
89:  plt 256,L,2;pen
90:  plt 0,L,1
91:  for I=1 to M
92:  NI+L→r3
93:  plt 0,r3,2
94:  plt 1.7,r3,2
95:  plt 0,r3,2
96:  next I
97:  for I=1 to 10
98:  plt 25I,r3,2
```

```
 99:  plot 25I,r3-(U-L)/150,2
100:  plt 25I,r3,2
101:  next I
102:  plt 256,r3,2
103:  for I=M to 1 by -1
104:  N(I-1)+L→r3
105:  plt 256,r3,2
106:  plt 254.3,r3,2
107:  plt 256,r3,2
108:  next I;pen
109:  fxd 0
110:  csiz 1.2,1,.75
111:  for I=1 to 6
112:  plt 50(I-1)-10,L-2,1
113:  lbl (L-1)D/5
114:  next I
115:  plt 90,L-5,1
116:  lbl "frequency (hz)";pen
117:  ret
118:  "Sub 2":
119:  fxd 1
120:  plt -21,L+12,1
121:  csiz 1.2,1,.75,90
122:  if r4=1;jmp 3
123:  lbl "spectrum level (db re 1 micro pa)"
124:  jmp 2
125:  lbl "level in",1.5D/250," hz bands (db re 1 v)"
126:  csiz 1.2,1,.75
127:  fxd 0
128:  for I=M+1 to 1 by -1
129:  plt -18,10(I-1)+L,1
130:  lbl 10(I-1)+L
131:  next I
132:  plt 6,.96(U-L)+L,1
133:  lbl C$[1,32]
134:  cplt 3,0;lbl I$[1,20]
135:  plt 6,.93(U-L)+L,1
136:  lbl C$[97,128]
137:  if r5=1;fxd 1;cplt 2,0;lbl "oa level=",A," db"
138:  plt 0,A[1]
139:  for I=1 to 255
140:  plt I,A[I]
141:  plt I,A[I+1]
142:  next I
143:  plt 256,A[256];pen
144:  plt 6,.9(U-L)+L,1
145:  lbl "comments on plot= ",D$
146:  plt 6,.87(U-L)+L,1
147:  lbl "sta= ",W$[1,3], "hyd dep= ",W$[8,11],"m"
148:  cplt 2,0;lbl "near hi= ",W$[17,20]," attn= ",W$[25,29],"db"
149:  plt 6,.84(U-L)+L,1
150:  lbl "rng= ",W$[4,7]," km tide= ",W$[12,16]
151:  cplt 1,0;lbl "near lo==,W$[21,24]," gain=",W$ 30,34,"db";pen
```

```
152:  ret
153:  "Sub 3":
154:  fxd 8
155:  0→K
156:  for K=1 to 100
157:  161.36-10.63ln(2K)→B[K]
158:  next K
159:  for K=101 to 256
160:  135.29-5.72ln(2K)→B[K]
161:  next K
162:  ret
163:  "Sub 4":
164:  fxd 8
165:  0→K
166:  for K=1 to 50
167:  161.36-10.63ln(4K)→B[K]
168:  next K
169:  for K=51 to 256
170:  135.29-5.72ln(4K)→B[K]
171:  next K
172:  ret
173:  "Sub 5":
174:  fxd 8
175:  0→K
176:  for K=1 to 20
177:  161.36-10.63ln(10K)→B[K]
178:  next K
179:  for K=21 to 105
180:  135.29-5.72ln(10K)→B[K]
181:  next K
182:  for K=106 to 190
183:  94.62+.0009125(10K)→B[K]
184:  next K
185:  for K=191 to 256
186:  17.65+10.43ln(10K)→B[K]
187:  next K
188:  ret
189:  "Sub 6":
190:  for I=1 to 256
191:  A[I]+B[I]+val(W$[25,29])-val(W$[30,34]→A[I]
192:  next I
193:  0→A
194:  for J=6 to 251
195:  tn^(A[J]/10)→G[J]
196:  G[J]+ A→A
197:  next J
198:  if r6=0;4.8→H
199:  if r6=1;7.8→H
200:  if r6=2;11.8→H
201:  10log(A)+H→A
202:  gsb "Sub 2"
203:  ret
```

```
204:   "Sub 7":
205:   fxd 8
206:   0→E
207:   0→S
208:   0→V
209:   for E=58 to 68
210:   tn^(A[E]/10)→P[E]
211:   P[E]+S→S
212:   next E
213:   10log(S)+4.8→S
214:   for E=116 to 316
215:   tn^(A[E]/10)→P[E]
216:   P[E]+V→V
217:   next E
218:   10log(V)+4.8→V
219:   fxd 1
220:   plt 6,.81(U-L)+L,1
221:   lbl "1/3-obl(db): 125hz=",S," 250hz=",V
222:   ret
223:   "Sub 8":
224:   fxd 8
225:   0→E
226:   0→S
227:   0→V
228:   0→W
229:   for E=30 to 35
230:   tn^(A[E]/10)→P[E]
231:   P[E]+S→S
232:   next E
233:   10log(S)+7.8→S
234:   for E=59 to 69
235:   tn^(A[E]/10)→P[E]
236:   P[E]+ V→V
237:   next E
238:   10log(V)+7.8→V
239:   for E=116 to 316
240:   tn^(A[E]/10)→P[E]
241:   P[E]+ W→W
242:   next E
243:   10log(W)+7.8→W
244:   fxd 1
245:   plt 6,.81(U-L)+L,1
246:   lbl"1/3-obl(db): 125hz=",S," 250hz=",V," 500hz=",W
247:   ret
248:   "Sub 9":
249:   fxd 8
250:   0→E
251:   0→S
252:   0→V
253:   0→W
254:   0→X
255:   0→Y
256:   for E=13 to 14
```

```
257:  tn^(A[E]/10)→P[E]
258:  P[E]+S→S
259:  next E
260:  10log(S)+11.8→S
261:  for E=24 to 28
262:  tn^(A[E]/10)→P[E]
263:  P[E]+V→V
264:  next E
265:  10log(V)+11.8→V
266:  for E=47 to 55
267:  tn^(A[E]/10)→P[E]
268:  P[E]+W→W
269:  next E
270:  10log(W)+11.8→W
271:  for E=93 to 101
272:  tn^(A[E]/10)→P[E]
273:  P[E]+X→X
274:  next E
275:  10log(X)+11.8→X
276:  for E=185 to 217
277:  tn^(A[E]/10)→P[E]
278:  P[E]+Y→Y
279:  next E
280:  10log(Y)+11.8→Y
281:  fxd 1
282:  plt 6,.81(U-L)+L,1
283:  lbl "1/3-obl(db): 125hz=",S," 250hz=",V," 500hz=",W
284:  plt 61,.78(U-L)+L,1
285:  lbl "1000hz=",X," 2000hz=",Y
286:  ret
```

APPENDIX B

COMPUTER PROGRAM EXPLANATION

The following is a breakdown of important sections of the computer program given in Appendix A, for use with the HP 9825A calculator. The first numbers given refer to line number of the program, and numbers in parenthesis that follow the discussion are the limit on the number of characters that can be entered into the calculator for that line:

0-1: Program title;

2-3: dimensioning variables;

4: informs program user that everytime a "*" is seen at the end of the computer display, the "CONTINUE" key must be pressed;

5-12: determines computer spectrum input from the HP 3582A analyzer ("HP3582A") or recorded tape cartridge ("tape") data;

13: enter the input channel used on analyzer (1);

14: enter the day-time-group ("DTG") the spectrum was started (20);

15-29: calculator "talks" to the analyzer and records all display items in memory;

30-32: determines if data will be stored and plotted;

33: enter the sonobuoy station number (3);

34: enter the station range from shore in kilometers (4);

35: enter the depth of the hydrophone at the above station in meters (4);

36: enter the current tidal condition when the spectrum started (4);

37: enter the nearest time of a high tide with respect to when the spectrum started (4);

38: enter the nearest time of a low tide with respect to when the spectrum started (4);

39: enter the "attenuation" required (dB) from Table III based on the taperecorder channel inputed to the analyzer (5);

40: enter the total "gain" required (dB) from Table III based on taperecorder channel inputed to the analyzer and the analyzer scale selected (5);

41: enter comments for the plot (usually noting the type surf condition) (60);

42: enter the track onto which raw spectrum data will be recorded (only a "0" or "1");

43: enter the file number onto which the raw spectrum data will be recorded (with no changes to this program to this point, a memory size of at least 4386 bytes is required) (2);

44-45: records the spectrum and data from steps 15-41;

46-48: pauses the program to remind user to have paper on the plotter and then loads the data just recorded into the calculator for further manipulation;

49-57: allows for a plot to be made of only the raw spectrum data without connections for system response or calculation of band levels;

58-65: allows for a corrected plot of the raw spectrum data just plotted, and if not desired, returns the program to line 4 (only the 2.5 kHz, 1.0 kHz, or 500 Hz scales can be used on the analyzer for corrected system response plots);

66-79: allows for a plot corrected for system response when a raw data plot was not desired - to continue taking data, the "CONTINUE" key is pressed, the program returns to line 4, and the analyzer can accept a new input signal (end of main program).

The subroutines of this program are extremely important, each performing a critical function or calculation leading to the final result of a plot corrected for system response. The subroutines are numbered "Sub 1" to "Sub 9", and a description of each follows:

"Sub1": sets the scale of the plot to be made based on the analyzer scale selected, traces the boarder that will surround the plot, and labels the horizontal axis ("FREQUENCY (HZ)") before returning to the main program;

"Sub2": labels the vertical axis (dB levels corresponding to the type plot selected) and prints five to seven lines at the top of the plot as follows (indicating from which line of the main program the information comes):

1st line - channel input to analyzer, full scale channel input sensitivity, and analyzer scale (23-24); day-time-group the spectrum started (14);

2nd line - number of averages used and bandwidth based on analyzer scale (23-24); overall band level of the spectrum calculated in "Sub6" (the final value is obtained from line 201) - not calculated for "raw data" plots;

3rd line - comments for plot (41);

4th line - buoy station number (33); hydrophone depth (35); nearest time of high tide (37); "attenuation" used during recording (39);

5th line - range from shore to buoy station (34); tide condition when plot started (36); nearest time of low tide (38); "gain" required based on tape channel and analyzer scale (40);

6th line - 1/3-octave band levels, calculated from subroutines "Sub7", "Sub8", or "Sub9" for center frequencies of 125 Hz (213) and 250 Hz (218) for 500 Hz scale ("Sub7"), for center frequencies of 125 Hz (233 or 260), 250 Hz (238

or 265), and 500 Hz (243 or 265) for
the 1.0 kHz scale ("Sub8") or the
2.5 kHz scale ("Sub9") (not calculated
for "raw data" plots);

7th line - 1/3-octave band levels for only the 2.5 kHz scale plots for center frequencies of 1000 Hz (275) and 2000 Hz (280) (not calculated for "raw data" plots).

Subroutines "Sub3", "Sub4", and "Sub5" calculated hydrophone sensitivity levels, based on the analyzer scale selected, to be used in calculation of absolute levels for each of the 256 bins of the analyzer:

"Sub3": 500 Hz scale hydrophone sensitivity levels;

"Sub4": 1.0 kHz scale hydrophone sensitivity levels;

"Sub5": 2.5 kHz scale hydrophone sensitivity levels.

Subroutine "Sub6" is the major calculation portion of the entire program, utilizing eq. (3) and assigning each of the 256 bins a value for absolute spectrum levels. This calculation is the reason a 2-3 second pause is noted during plotter operation after the horizontal axis is labeled ("FREQUENCY (HZ)"):

"Sub6": calculates absolute spectrum levels and assigns values to 256 bins (191); calculates overall band levels for "corrected plots" based on analyzer scale selected (201);

Subroutines "Sub7", "Sub8", and "Sub9" calculate hydrophone sensitivity levels based on the analyzer scale selected for use in "Sub6" calculations and plot display via "Sub2". (The levels are calculated as positive values to be added to other values in eq. (3) vice negative values that would be subtracted):

"Sub7": calculates 1/3-octave band levels for the 500 Hz analyzer scale for center frequencies of 125 Hz (213) and 250 Hz (218);

"Sub8": calculates 1/3-octave band levels for the 1.0 kHz analyzer scale for center frequencies of 125 Hz (233), 250 Hz (238), and 500 Hz (243);

"Sub9": calculates 1/3-octave band levels for the 2.5 kHz analyzer scale for center frequencies of 125 Hz (260), 250 Hz (265), 500 Hz (270), 1000 Hz (275), and 2000 Hz (280).

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